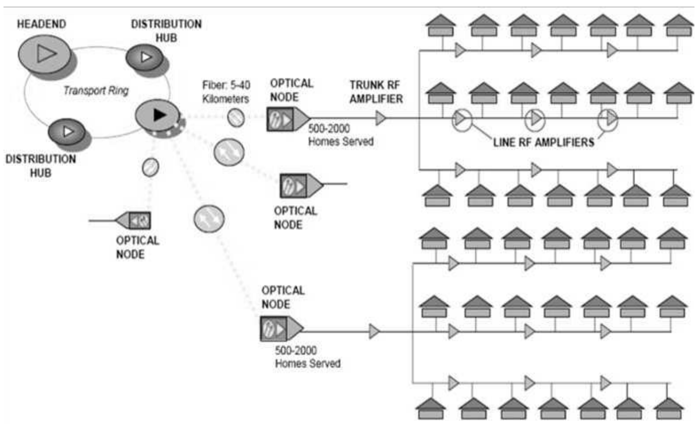
Engineering Standards & Technology Overview

CLEARFIELD
Ingenuity in Passive Connectivity

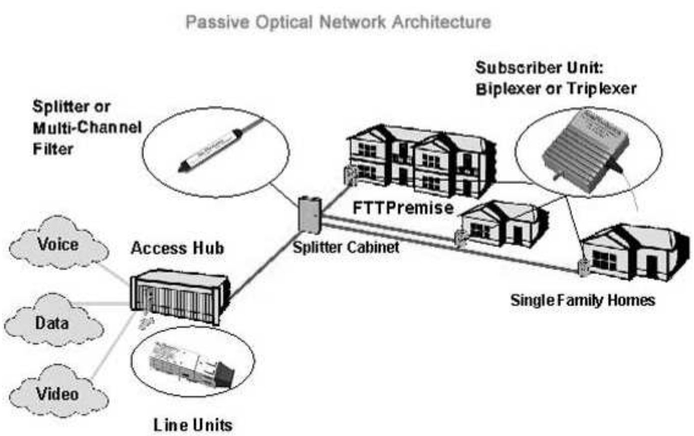
Optical Splitters Product Notes

Optical splitters are used in CATV and FTTH PON (Passive Optical Network) architectures.

CATV/HFC (Hybrid Fiber-Coax)



PON (Passive Optical Networks)



A hybrid fiber coaxial (HFC) network is a telecommunication technology in which optical fiber cable and coaxial cable are used in different portions of a network to carry broadband content (such as video, data, and voice). Optical splitters are used to split the signal coming from the Erbium Doped Fiber Amplifier (EDFA). In this way, one EDFA can feed several nodes (up to 12 depending on distance limitations). The splitters are located in the Headend/CO.

The leading FTTH technology is PON or Passive Optical Network technology. This approach differs from most of the telecommunications networks in place today by featuring "passive" operation. Active networks like DSL, VDSL and cable have active components in the network backbone equipment, in the central office, in the neighborhood network infrastructure, and in the customer premises equipment. PONs have only passive light transmission components in the neighborhood infrastructure with active components only in the central office and the customer premises equipment. The elimination of active components means that the access network consists of one bi-directional light source and a number of passive splitters that divide the data stream into the individual links to each customer. At the central office, the termination point is in PON optical line terminal (OLT) equipment. At the customer premises, the termination point is in optical network terminals or ONTs also called optical network units or ONUs. These are in the customer premises equipment or CPE. Between the OLT and the ONT/ONUs is the passive optical network comprising fiber links and passive splitters and couplers.

Two primary technologies are commonly used to fabricate splitters and couplers.

Planar Lightwave Circuit (PLC or Planar). A light circuit on an 'optical chip' is mounted on a carrier and fibers, usually in ribbon form, are bonded to the edges of the chip. The assembly is encapsulated in a protective enclosure. PLC devices support direct split counts up to 32. In planar fabrication technology, devices are made using ion-exchange or photolithography techniques that replicate solid-state circuit methods. Ultimately, the per-unit cost for the expected high volumes will become advantageous for planar technology, especially for higher port devices. A difficult manufacturing problem involves a low-loss method for attaching the optical fibers to the chip and then passing the market's qualification and reliability requirements.

Type	IL	RL	PDL	Uniformity	Directivity	Operating Temp	Storage Temp
1x32	< 16.8 dB	> 50 dB	< .3 dB	< 1.7 dB	> 55 dB	-40 to 85 C	-40 to 85 C
1x16	< 13.8 dB	> 50 dB	< .3 dB	< 1.2 dB	> 55 dB	-40 to 85 C	-40 to 85 C
1x8	< 10.8 dB	> 50 dB	< .3 dB	< 0.8 dB	> 55 dB	-40 to 85 C	-40 to 85 C
1x4	< 7.5 dB	> 50 dB	< .3 dB	< 0.6 dB	> 55 dB	-40 to 85 C	-40 to 85 C

**Terminated Specifications

FBT Splitter Specifications

Fused Biconic Technology (FBT). Two or more fibers are twisted together, heated and drawn to bring the optical cores into near contact. The combined fibers are mounted on a low-expansion carrier and encapsulated in a low expansion tube. FBT devices allow direct splitting up to 4 ways. Higher split counts are achieved by splicing multiple devices to form multi-stage, concatenated splitters. Concatenated splitters are also called tree splitters. The fused-biconic tapered technology directly bonds or melts the fibers together so that the final splitter can be mounted in small diameter (approximately 3-millimeter) stainless-steel tubes. This technology produces small, low-cost, high-performance devices. A tough fabrication obstacle involves the small and delicate final coupling region. However, when properly mounted and packaged, these devices meet long-term stability and reliability requirements.

Dual Window – Wavelength Flattened (Terminated Specifications)						
		1x2	1x4	1x8	1x16	1x32
Max. Insertion Loss	dB	3.6	7.2	10.7	14.0	17.6
Max. Uniformity	dB	0.8	1.0	1.3	1.6	1.9
Max. PDL	dB	0.2	0.3	0.4	0.5	0.6
Center Wavelengths nm		1310 and 1550				

Engineering Standards & Technology Overview

WDM Product Notes

DWDM uses up to 160 different colors (also known as lambdas or channels) to provide high-capacity bandwidth across an optical fiber network. Each lambda carries an individual optical signal providing the same bandwidth per channel (approximately 2.4G bit/sec with most of today's fiber) as a single light stream.

It is easy to understand WDM. Consider the fact that you can see many different colors of light - red, green, yellow, blue, etc. all at once. The colors are transmitted through the air together and may mix, but they can be easily separated using a simple device like a prism, just like we separate the "white" light from the sun into a spectrum of colors with the prism.

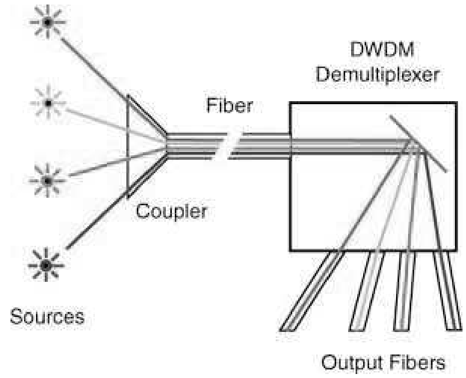
This technique was first demonstrated with optical fiber in the early 80s when telco fiber optic links still used multimode fiber. Light at 850 nm and 1300 nm was injected into the fiber at one end using a simple fused coupler. At the far end of the fiber, another coupler split the light into two fibers, one sent to a silicon detector more sensitive to 850 nm and one to a germanium or InGaAs detector more sensitive to 1300 nm. Filters removed the unwanted wavelengths, so each detector then was able to receive only the signal intended for it.

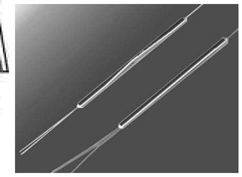
The input end of a WDM system is really quite simple. It is a simple coupler that combines all the inputs into one output fiber. These have been available for many years, offering 2, 4, 8, 16, 32 or even 64 inputs. It is the de-multiplexer that is the difficult component to make.

A WDM system has some features that make them very useable. Each wavelength can be from a normal link, for example a OC-48 link, so you do not obsolete most of your current equipment. You merely need laser transmitters chosen for wavelengths that match the

WDM de-multiplexer to make sure each channel is properly decoded at the receiving end. If you use an OC-48 SONET input, you can have 4X2.5 GB/s = 10 GB/s up to 32 X 2.5 GB/s = 80 GB/s. While 32 channels are the maximum today, future enhancements are expected to offer 80-128 channels! And you are not limited to SONET, you can use Gigabit Ethernet for example, or you can mix and match SONET and Gigabit Ethernet or any other digital signals! You can even mix in analog/RF channels like CATV, as is done with EPON/BPON/GPON FTTH systems.

Originally, the term "Coarse Wavelength Division Multiplexing" was fairly generic, and meant a number of different things. In general, these things shared the fact that the choice of channel spacings and frequency stability was such that erbium doped fiber amplifiers (EDFAs) could not be utilized. Prior to the relatively recent ITU standardization of the term, one common meaning for Coarse WDM meant two (or possibly more) signals multiplexed onto a single fiber, where one signal was in the 1550-nm band, and the other in the 1310-nm band.





DWDM Demultiplexer

Recently the ITU has standardized a 20 nanometer channel spacing grid for use with CWDM, using the wavelengths between 1310 nm and 1610 nm. Many CWDM wavelengths below 1470 nm are considered "unusable" on older G.652 specification fibers, due to the increased attenuation in the 1310-1470 nm bands. Newer fibers which conform to the G.652.C and G.652.D standards, such as Corning SMF-28e and Samsung Wide pass nearly eliminate the "water peak" attenuation peak and allow for full operation of all twenty ITU CWDM channels in metropolitan networks.

A relatively recent development relating Coarse WDM is the creation of GBIC and Small Form Factor Pluggable (SFP) transceivers utilizing standardized CWDM wavelengths. GBIC and SFP optics allow for something very close to a seamless upgrade in even legacy systems that support SFP interfaces. Thus, a legacy switch system can be easily "converted" to allow wavelength multiplexed transport over a fiber simply by judicious choice of transceiver wavelengths, combined with an inexpensive passive optical multiplexing device.

Engineering Standards & Technology Overview

WDM Specifications

200 Ghz DWDM

Parameter	Unit	Value				
		Add/Drop	4CH	8CH	16CH	20CH
Wavelength Range	nm	1520-1560				
Central Wavelength		ITU-T GRID				
Bandwidth	nm	c +/-0.25				
Insertion Loss	dB	<0.8	<2.0	<3.0	<3.5	<4.0
Insertion Loss (Reflection)	dB	<0.3	na	na	na	na
Isolation	dB	>28				
Isolation (Reflection)	dB	>12	na	na	na	na
Uniformity of I.L.	dB	na	<1	<1	<1	<1
PDL	dB	<0.2				
Return Loss	dB	>45				
Operation Temperature	ºC	-5 -65				
Storage Temperature	ºC	-40 -85				
Maximum Input Power	mW	500				
Mechanical Dimension	mm	3.6 (D) x 40 (L)	100 x 80 x 8	100 x 80 x 8	100 x 80 x 16	100 x 80 x 16

100 Ghz DWDM

Parameter	Unit	Value				
		Add/Drop	4CH	8CH	16CH	40CH
Wavelength Range	nm	1520-1560				
Central Wavelength		ITU-T GRID				
Bandwidth	nm	c +/-0.11				
Insertion Loss	dB	<0.8	<2.5	<3.5	<4.0	<5.5
Insertion Loss (Reflection)	dB	<0.3	na	na	na	na
Isolation	dB	>28				
Isolation (Reflection)	dB	>12	na	na	na	na
Uniformity of I.L.	dB	na	<1	<1	<1	<1
PDL	dB	<0.2				
Return Loss	dB	>45				
Operation Temperature	ºC	-5 -65				
Storage Temperature	ºC	-40 -85				
Maximum Input Power	mW	500				
Mechanical Dimension	mm	3.6 (D) x 40 (L)	100 x 80 x 8	100 x 80 x 8	100 x 80 x 16	100 x 80 x 16

Engineering Standards & Technology Overview

WDM Specifications

CWCM

Parameter	Unit	Value		
		Add/Drop	4CH	8CH
Wavelength Range	nm	1741-1611		
Bandwidth	nm	c +/-6.5		
Insertion Loss	dB	<0.8	<2.0	<3.0
Insertion Loss (Reflection)	dB	<0.3	na	na
Isolation	dB	>30		
Isolation (Reflection)	dB	>12	na	na
Uniformity of I.L.	dB	na	<1	<1
PDL	dB	<0.2		
Return Loss	dB	>45		
Operation Temperature	°C	-5 -85		
Maximum Input Power	mW	500		
Mechanical Dimension	mm	3.6 (D) x 40 (L)	100 x 80 x 8	100 x 80 x 8

FSAN WDM

WDM (EWDM) Specifications			
Parameter	Ports	Unit	Specifications
Pass Channel Wavelength	P1 --> P3	nm	1260-1360
			1480-1500
Reflect Channel Wavelength	P1 --> P2	dB	1540-1565
Insertion Loss	P1 <--> P3	dB	<0.8
		dB	<0.5
Isolation		dB	>25
		dB / °C	>18
PDL		dB	<0.2
Ripple		dB	<0.3
PDL		dB	<0.2
Return Loss		dB	>45
Operating Temperature Range		°C	-5 - 65
Storage Temperature Range		°C	-40 - 85
Maximum Input Power		mW	500
Mechanical Dimension		*mm*	3.6 (D) x 40 (L)

Engineering Standards & Technology Overview

CLEARFIELD
Ingenuity in Passive Connectivity

Fiber Optic Cable Assemblies

Scope
This Engineering Specification is written to provide a summary of the performance criteria for terminated optical fiber connectors on optical fiber cable. This document will summarize product performance requirements based on the following established criteria: EIA/TIA-455, Fiber Optic Test Procedures (FOTP), and parts of Bellcore GR-326-CORE, Issue 3. This document may be revised, without notice, in accordance with standard CLEARFIELD document change procedures.

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Applicable Documents
The following documents form a part of this specification to the extent defined herein. In the event of a conflict, this document shall govern:

GR-326-CORE	Generic Requirements for Singlemode Optical Connectors and Jumper Assemblies, Issue 3
EIA/TIA-455	Fiber Optic Test Procedures (FOTP), EIA/TIA
CLEARFIELD Drawing #17012	Connector End-face Polish Geometry, CLEARFIELD
CLEARFIELD Drawing #17010	Specification for Singlemode Connector End-face Visual Inspection Criteria
CLEARFIELD Drawing #17011	Specification for Multimode Connector End-Face Visual Inspection Criteria
ITU-T G.652.D (06/05)	Characteristics of Singlemode Optical Fiber and Cable
ITU-T G.657 Class A (12/2006)	Characteristics of A Bending Loss Insensitive Singlemode Optical Fiber and Cable for the Access Network

General Product Descriptions
Optical Fiber:
Singlemode full Spectrum fiber meets ITU-T G.652.D (06/05) specification. Reduced Water Peak (RWP) fibers are considered Full Spectrum because the reduction of loss in the water absorption spectral region (the E band)

Singlemode Bending Loss Insensitive optical fiber meets ITU-T G.657 Class A (12/06) Fully compliant with the G.652 singlemode fibers specification

Multimode 50/125um Graded Index Optical Fiber meets ITU-T G.651 (02/98)
Multimode 50/125um Graded Index Optical Fiber for the optical access network meets ITU-T G.651.1 (07/07)

Optical fiber cable for the optical access network recommends a quartz multimode fiber to be used for the access network in specific environments

Color Coding of Fiber Optic Cable must be in accordance with TIA/EIA 598-A

Fiber Optic Jacketing: All riser and plenum cables will meet requirements described in TR-NWT-000409. Fiber optic cable for plenum environments shall be NEC type OFNP and listed as UL 910. Fiber optic cable for riser environments shall be listed as NEC type OFNR and listed as UL 1666. Fiber optic cable for outside plant environments shall meet Bellcore GR-20-CORE requirements.

Connectors Optical Fiber:

GR-326-CORE	Generic Requirements for Singlemode Optical Connectors and Jumper Assemblies, Issue 3

Performance Requirements
The following specifications refer to terminated optical fiber connectors on optical fiber cable. All measurements performed using standard procedures with a non-contacting interferometer. Insertion Loss and Return Loss figures are measured using a launch cable meeting the criteria specified in WIO 900.14.

Minimum Performance Specifications for Terminated Multimode Connectors				
Connector Type	Ferrule Material	Polish Type	Typical Ins. Loss (dB)	Max. Ins. Loss (dB)
ST	Ceramic	PC	0.25	≤ 0.50
SC	Ceramic	PC	0.25	≤ 0.50
FC	Ceramic	PC	0.25	≤ 0.50
LC	Ceramic	PC	0.25	≤ 0.50
ST	Stainless Steel	Flat	0.40	≤ 0.75
MTRJ	Thermoplastic	Flat	0.50	≤ 0.50
MPO/MPT	Thermoplastic	Flat	0.50	≤ 0.50

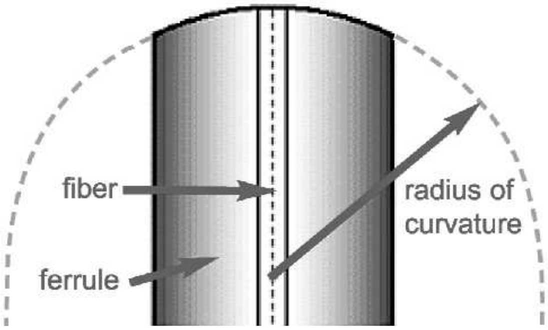
Minimum Performance Specifications for Terminated Singlemode Connectors										
Connector Type	Ferrule Material	Polish Type	Ins. Loss, Typical (dB)	Max. Ins. Loss (dB)	Min. Ret. Loss (dB)	Polish Radius (mm)	Fiber Height, Max (nm)	Fiber Height, Typical (nm)	Apex Offset (μm)	Polish Angle
ST	Ceramic	UPC	0.15	0.30	55.00	7 - 25	± 100	± 50	< 50	N/A
SC	Ceramic	UPC	0.15	0.30	55.00	7 - 25	± 100	± 50	< 50	N/A
FC	Ceramic	UPC	0.15	0.30	55.00	7 - 25	± 100	± 50	< 50	N/A
LC	Ceramic	UPC	0.15	0.30	55.00	7 - 25	± 100	± 50	< 50	N/A
D4	Ceramic	UPC	0.15	0.30	55.00	7 - 25	± 100	± 50	< 50	N/A
SC	Ceramic	APC	0.20	0.30	65.00	5 - 12	± 100	± 100	< 100	$8.0° \pm 0.5°$
FC	Ceramic	APC	0.20	0.30	65.00	5 - 12	± 100	± 100	< 100	$8.0° \pm 0.5°$
LC	Ceramic	APC	0.20	0.30	65.00	5 - 12	± 100	± 100	< 100	$8.0° \pm 0.5°$

Note: All CLEARFIELD fiber optic patch cords are designed and tested to operate between - 40 and + 80 degrees Celsius.

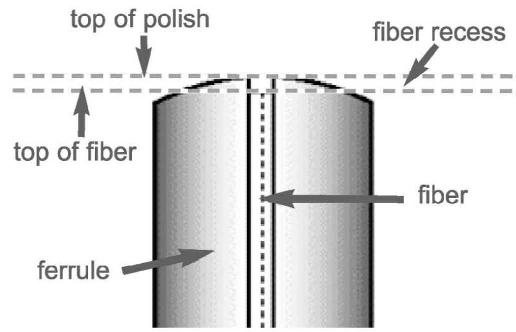
ENGINEERING STANDARDS & TECHNOLOGY

Engineering Standards & Technology Overview

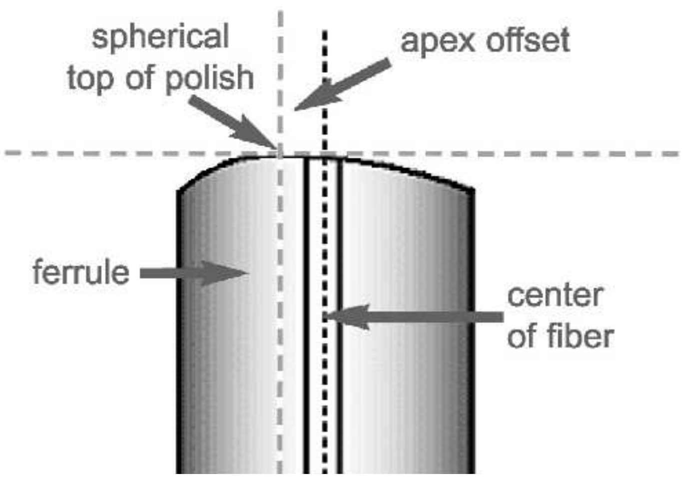
Specifications



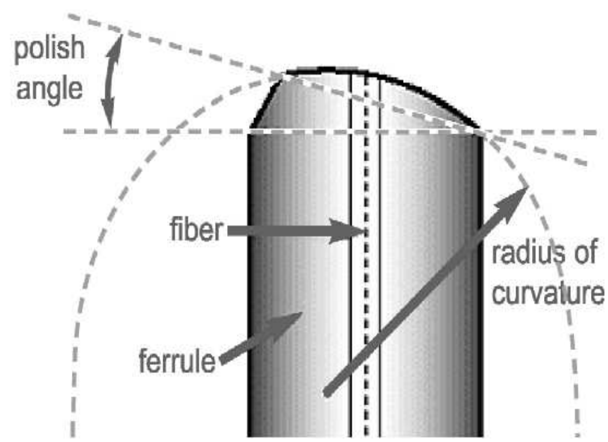
1.0 POLISH RADIUS
The radius of curvature is defined as the radius of the end-face surface as measured from the ferrule axis.



2.0 FIBER UNDERCUT / PROTRUSION
Fiber undercut or protrusion is defined as the distance between the top of the glass fiber as measured against the surrounding material in a spherical plane.
Undercut = -.02R3 + 1.3R2 - 31R + 325.



3.0 APEX OFFSET
Apex offset is measured as the distance between the spherical center of the polished end-face and the center of the fiber.



4.0 ANGLED POLISH
The end face is polished at an angle relative to the axis perpendicular to the ferrule axis.

ENGINEERING STANDARDS & TECHNOLOGY

Engineering Standards & Technology Overview

End-face

What is I.L.?
Insertion loss (I.L.) is the loss of signal power resulting from the insertion of a device in a transmission line or optical fiber. Usually expressed as a ratio in dB relative to the transmitted signal power, it can also be referred to as attenuation.

What is R.L.?
Return loss or reflection loss (R.L.) is the reflection of signal power resulting from the insertion of a device in a transmission line or optical fiber. It is usually expressed as a ratio in dB relative to the transmitted signal power.

Test and Measurement
Your minimum requirements should include data that meets insertion loss and return loss (reflectance). Insertion loss should meet the 326-Core minimum of .4dB, with reflectance meeting 55dB for UPC connectors and 65dB for APC. Asking the typical performance measures of a manufacturer's process can save you on link loss budgets over a long fiber run through a FTTH network.

Apex offset, the measurement for how well the center core of the fiber is centered in relationship to the spherical apex of the polished tip, minimizes lateral offset between two fibers and maintains a better physical contact. Apex offset describes a physical condition of the polished fiber, rather than a performance parameter. It is also an acceptance criteria for Telcordia. An excessive apex offset contributes to high insertion loss and high back reflection readings.

Fiber undercut or protrusion affects the physical contact zone. This metric measures, in nanometers, the height of the fiber under or below the ceramic end-face. Too much undercut minimizes the chance of a good physical contact, while too much causes excessive fiber deformation when mating occurs resulting in degradation of signal. When two connectors are mated, the ceramic compresses around the fiber core which allows the fibers to squeeze up and make good contact with each other. When they do not touch (because of too much undercut), an air gap is created and loss happens. If the fiber is protruding too far (beyond 50nm), chipping and cracking can occur during the mate.

Radius of curvature is the measurement of the connector end-face spherical condition. The radius generated affects the performance because the radius, when mated with another connector, should be compressing most of the material surrounding the core (ceramic ferrule). A proper radius, 5 to 12mm, allows for the right compression and max performance. Too tight of a radius will put too much compression on the glass and too loose will put too much on the surrounding ferrule with not enough compression. Too much or too little radius can cause light scatter or inadequate physical contact for optimal signal transfer.

Apex offset, fiber undercut/protrusion, and radius of curvature are the main ingredients that work in concert to deliver good IL and RL performance. Processes that drift out of this geometry range can still yield acceptable IL/RL, but sensitive traffic will be affected (such as video) and long term performance of the connector will be compromised.

Your vendor should be able to provide these geometry test reports with on-hand interferometer testing. While you may not require this data for each and every connector, you should require that random testing is being performed to ensure the process is capable and not drifting out of spec. "Garage shops" will not be able to deliver this test data on demand.

Your test reports should account for each connector independently and not a total report that summarizes both ends.

End-face Quality & Cleanliness
Currently, there is not an industry standard for this topic. To be sure, end-face and cleanliness has a direct impact on the performance of the connector.

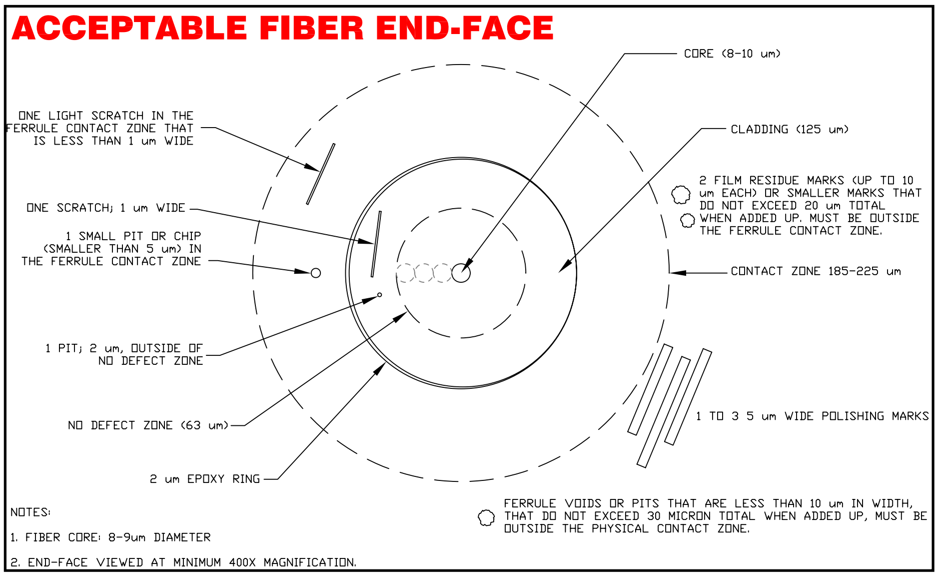
Several organizations (most notably, NEMI) have studied the impact of end-face defects and cleanliness. The influence of the contamination/scratches becomes more evident if they are located in the core/cladding areas. Particle contamination can cause a significant increase in IL (up to 10 times) and decrease in RL (up to 3 times). Scratches applied to the fiber contact zones 1a and 1b, which is an area from the core out to the cladding (125um), decreased RL by up to 25%. On the other hand, scratches located in the cladding layer showed little effect on IL and RL. Multiple heavy scratches passing through the core caused severe performance degradation in IL/RL and can be catastrophic.

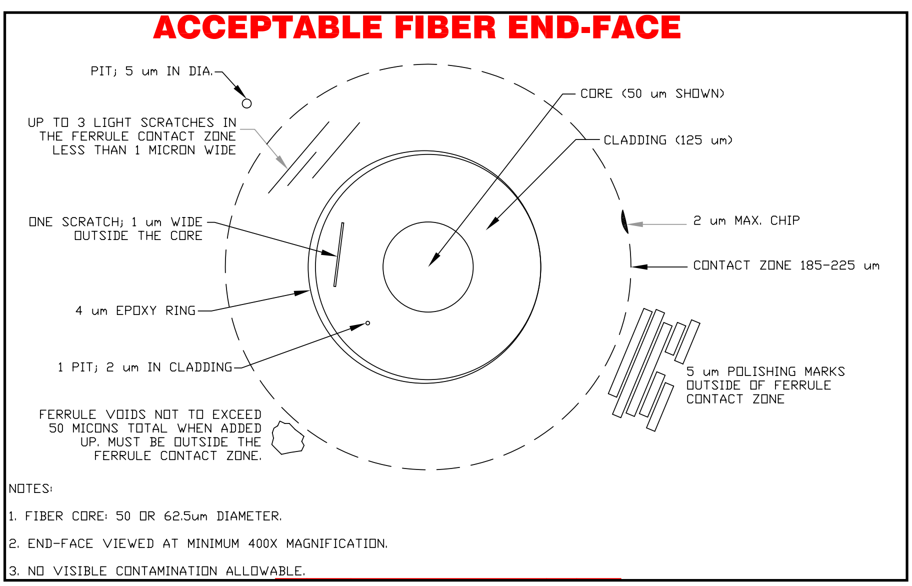
Connectors with particle contamination will pass on contamination to mated connectors. Contaminant can prevent direct physical contact, creating an air gap. Multiply this by the number of re-mates over time and the problem spreads. Pits and scratches, in the critical contact zone 1a, will collect particulates over time and the same contamination-spread occurs. Long term reliability in dynamic circuits is severely reduced as opposed to those that are static. Scratches and polishing marks outside of critical contact areas are acceptable and do not have any impact on signal performance.

The quality fiber assembly manufacturers and OEMs will have their own inspection criteria. However, these specifications differ from company to company and the differences can cause materials to be "nonconforming" at user/customer sites.

Engineering Standards & Technology Overview

End-face





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