Section 1: Introduction to Fiber Optics and Optical Interconnection Technology

1. From Theory to Practical Application: A Quick History Of Fiber Optics

An important principle in physics became the theoretical foundation for optical fiber communications: light in a glass medium can carry more information over longer distances than electrical signals can carry in a copper or coaxial medium.

The first challenge undertaken by scientists was to develop a glass so pure that one percent of the light would be retained at the end of one kilometer (km), the existing unrepeatered transmission distance for copper-based telephone systems. In terms of attenuation, this one-percent of light retention translated to 20 decibels per kilometer (dB/km) of glass material.

Glass researchers all over the world worked on the challenge in the 1960s, but the breakthrough came in 1970, when Corning scientists Drs. Robert Maurer, Donald Keck, and Peter Schultz created a fiber with a measured attenuation of less than 20 dB per km. It was the purest glass ever made. The three scientists' work is recognized as the discovery that led the way to the commercialization of optical fiber technology. Since then, the technology has advanced tremendously in terms of performance, quality, consistency, and applications.

Working closely with customers has made it possible for scientists to understand what modifications are required, to improve the product accordingly through design and manufacturing, and to develop industry-wide standards for fiber.

The commitment to optical fiber technology has spanned more than 30 years and continues today with the endeavor to determine how fiber is currently used and how it can meet the challenges of future applications. As a result of research and development efforts to improve fiber, a high level of glass purity has been achieved. Today, fiber's optical performance is approaching the theoretical limits of silica-based glass materials. This purity, combined with improved system electronics, enables fiber to transmit digitized light signals well beyond 100 km (more than 60 miles) without amplification. When compared with early attenuation levels of 20 dB per km, today's achievable levels of less than 0.35 dB per km at 1310 nanometers (nm) and 0.25 dB per km at 1550 nm, testify to the incredible drive for improvement.

2. How Optical Fiber Works

The operation of an optical fiber is based on the principle of total internal reflection. Light reflects (bounces back) or refracts (alters its direction while penetrating a different medium), depending on the angle at which it strikes a surface.

One way of thinking about this concept is to envision a person looking at a lake. By looking down at a steep angle, the person will see fish, rocks, vegetation, or whatever is below the surface of the water (in a somewhat distorted location due to refraction), assuming that the water is relatively clear and calm. However, by casting a glance farther out, thus making the angle of sight less steep, the individual is likely to see a reflection of trees or other objects on an opposite shore. Because air and water have different indices of refraction, the angle at which a person looks into or across the water influences the image seen.

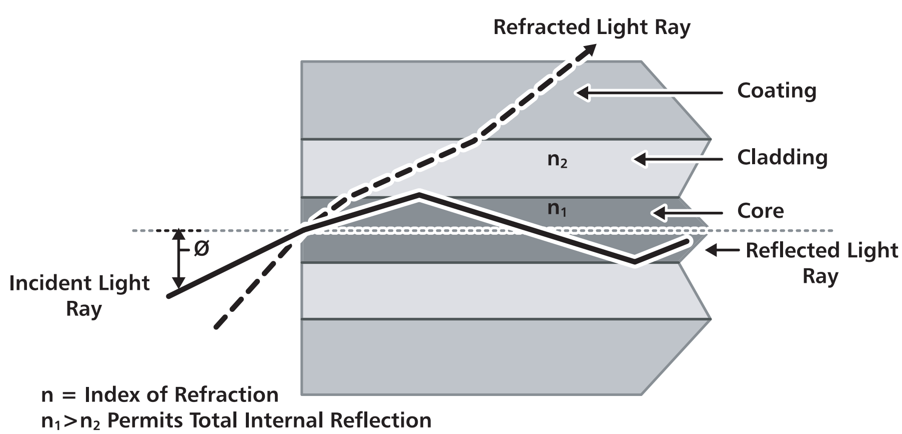
This principle is at the heart of how optical fiber works. Lightwaves are guided through the core of the optical fiber in much the same way that radio frequency (RF) signals are guided through coaxial cable. The lightwaves are guided to the other end of the fiber by being reflected within the core. Controlling the angle at which the light waves are transmitted makes it possible to control how efficiently they reach their destination. The composition of the cladding glass relative to the core glass determines the fiber's ability to reflect light. The difference in the index of refraction of the core and the cladding causes most of the transmitted light to bounce off the cladding glass and stay within the core. In this way, the fiber core acts as a waveguide for the transmitted light.

The Design of Fiber

Core, Cladding, and Coating

An optical fiber consists of two different types of highly pure, solid glass, composed to form the core and cladding. A protective acrylate coating (see Figure 1) then surrounds the cladding. In most cases, the protective coating is a dual layer composition.

Figure 1. Core, Cladding, and Coating



A protective coating is applied to the glass fiber as the final step in the manufacturing process. This coating protects the glass from dust and scratches that can affect fiber strength. This protective coating can be comprised of two layers: a soft inner layer that cushions the fiber and allows the coating to be stripped from the glass mechanically and a harder outer layer that protects the fiber during handling, particularly the cabling, installation, and termination processes.

Singlemode and Multimode Fibers

There are two general categories of optical fiber: singlemode and multimode (see Figure 2).

Figure 2. Singlemode and Multimode Fibers

Multimode fiber was the first type of fiber to be commercialized. It has a much larger core than singlemode fiber, allowing hundreds of modes of light to propagate through the fiber simultaneously. Additionally, the larger core diameter of multimode fiber facilitates the use of lower-cost optical transmitters (such as light emitting diodes [LEDs] or vertical cavity surface emitting lasers [VCSELs]) and connectors.

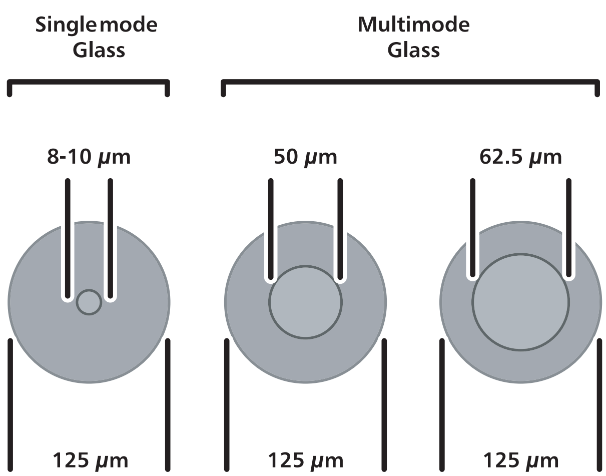
Singlemode fiber, on the other hand, has a much smaller core that allows only one mode of light at a time to propagate through the core. While it might appear that multimode fibers have higher capacity, in fact the opposite is true. Singlemode fibers are designed to maintain spatial and spectral integrity of each optical signal over longer distances, allowing more information to be transmitted.

Its tremendous information-carrying capacity and low intrinsic loss have made singlemode fiber the ideal transmission medium for a multitude of applications. Singlemode fiber is typically used for longer-distance and higher-bandwidth applications (see Figure 3). Multimode fiber is used primarily in systems with short transmission distances (under 2 km), such as premises communications, private data networks, and parallel optic applications.

Optical Fiber Sizes

The international standard for outer cladding diameter of most singlemode optical fibers is 125 microns (μm) for the glass and 245 μm for the coating. This standard is important because it ensures compatibility among connectors, splices, and tools used throughout the industry.
Standard singlemode fibers are manufactured with a small core size, approximately 8 to 10 μm in diameter.
Multimode fibers have core sizes of 50 to 62.5 μm in diameter.

Figure 3. Optical Fiber Sizes



Basic Optical Cable Design

There are two basic cable designs:

Loose-tube cable, used in the majority of outside-plant installations in North America, and tight-buffered cable, primarily used inside buildings.

The modular design of loose-tube cables typically holds up to 12 fibers per buffer tube with a maximum per cable fiber count of more than 200 fibers. Loose-tube cables can be all-dielectric or optionally armored. The modular buffer-tube design permits easy drop-off of groups of fibers at intermediate points, without interfering with other protected buffer tubes being routed to other locations. The loose-tube design also helps in the identification and administration of fibers in the system.

Single-fiber tight-buffered cables are used as pigtails, patch cords and jumpers to terminate loose-tube cables directly into opto-electronic transmitters, receivers and other active and passive components.

Multi-fiber tight-buffered cables also are available and are used primarily for alternative routing and handling flexibility and ease within buildings.

Loose-Tube Cable

In a loose-tube cable design, color-coded plastic buffer tubes house and protect optical fibers. A gel filling compound impedes water penetration. Excess fiber length (relative to buffer tube length) insulates fibers from stresses of installation and environmental loading. Buffer tubes are stranded around a dielectric or steel central member, which serves as an anti-buckling element. The cable core, typically uses aramid yarn, as the primary tensile strength member.

The outer polyethylene jacket is extruded over the core. If armoring is required, a corrugated steel tape is formed around a single jacketed cable with an additional jacket extruded over the armor.
Loose-tube cables typically are used for outside-plant installation in aerial, duct and direct-buried applications.

Tight-Buffered Cable

With tight-buffered cable designs, the buffering material is in direct contact with the fiber. This design is suited for "jumper cables" which connect outside plant cables to terminal equipment, and also for linking various devices in a premises network.

Multi-fiber, tight-buffered cables often are used for intra-building, risers, general building and plenum applications.

The tight-buffered design provides a rugged cable structure to protect individual fibers during handling, routing and connectorization. Yarn strength members keep the tensile load away from the fiber.

As with loose-tube cables, optical specifications for tight-buffered cables also should include the maximum performance of all fibers over the operating temperature range and life of the cable. Averages should not be acceptable.

3. Fiber Geometry: A Key Factor in Coupling and System Performance

As greater volumes of fiber in higher fiber-count cables are installed, system engineers are becoming increasingly conscious of the impact of splicing and connectors on their systems. Splice yields, connector counts and system losses have a profound impact on the quality of system performance and the cost of installation.

Glass geometry, the physical dimensions of an optical fiber, has been shown to be a primary contributor to splice loss and splice yield in the field as well as overall interconnect performance. Early on, one company recognized the benefit provided by tightly controlled fiber geometry and has steadily invested in continuous improvement in this area. The manufacturing process helps engineers reduce systems costs and support the industry's low maximum splice-loss requirement, typically at around 0.05 dB and reducing losses in connectors, typically less than .3 dB for the latest interconnect systems.

Fiber that exhibits tightly controlled geometry tolerances will not only be easier and faster to couple but will also reduce the need for testing by ensuring predictable, high-quality coupling performance. This is particularly true when fibers are spliced by passive, mechanical, or fusion techniques for both single fibers and fiber ribbons. In addition, tight geometry tolerances lead to the additional benefit of flexibility in equipment choice.

The benefits of tighter geometry tolerances can be significant. In today's fiber-intensive architectures, it is estimated that splicing, interconnect installation and testing can account for more than 30 percent of the total labor costs of system installation.

Fiber Geometry Parameters

The three fiber geometry parameters that have the greatest impact on splicing or interconnect performance include the following:

- cladding diameter—the outside diameter of the glass
- core/clad concentricity (or core-to-cladding offset)—how well the core is centered in the cladding glass region
- fiber curl—the amount of curvature over a fixed length of fiber

These parameters are determined and controlled during the fiber-manufacturing process. As fiber is cut and spliced according to system needs, it is important to be able to count on consistent geometry along the entire length of the fiber and between fibers and not to rely solely on measurements made.

Cladding Diameter

The cladding diameter tolerance controls the outer diameter of the fiber, with tighter tolerances ensuring that fibers are almost exactly the same size. During splicing, inconsistent cladding diameters can cause cores to misalign where the fibers join, leading to higher splice losses.

The drawing process controls cladding diameter tolerance. Some manufacturers are able to control the tolerance of the cladding to a level of 125.0±1.0 µm. Once the cladding diameter tolerance is tightened to this level, core/clad concentricity becomes the single largest geometry contributor to splice loss.

Core/Clad Concentricity

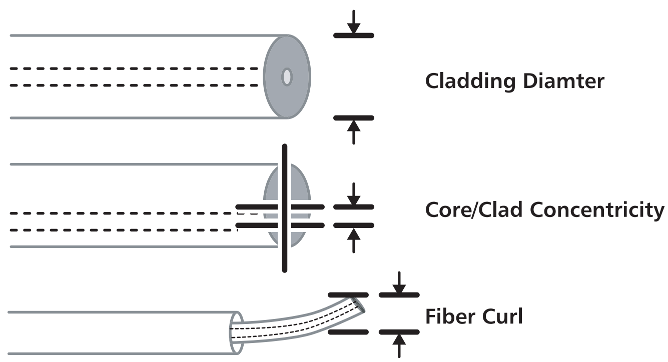
Tighter core/clad concentricity tolerances help ensure that the fiber core is centered in relation to the cladding. This reduces the chance of ending up with cores that do not match up precisely when two fibers are spliced together. A core that is precisely centered in the fiber yields lower-loss splices more often.

Core/clad concentricity is determined during the first stages of the manufacturing process, when the fiber design and resulting characteristics are created. During these laydown and consolidation processes, the dopant chemicals that make up the fiber must be deposited with precise control and symmetry to maintain consistent core/clad concentricity performance throughout the entire length of fiber.

Fiber Curl

Fiber curl is the inherent curvature along a specific length of optical fiber that is exhibited to some degree by all fibers. It is a result of thermal stresses that occur during the manufacturing process. Therefore, these factors must be rigorously monitored and controlled during fiber manufacture. Tighter fiber-curl tolerances reduce the possibility that fiber cores will be misaligned during splicing, thereby impacting splice loss.

Figure 8. Cladding Diameter, Core/Clad Concentricity, and Fiber Curl



4. How to Choose Optical Fiber

Singlemode Fiber Performance Characteristics

The key optical performance parameters for singlemode fibers are attenuation, dispersion, and mode-field diameter.

Optical fiber performance parameters can vary significantly among fibers from different manufacturers in ways that can affect your system's performance. It is important to understand how to specify the fiber that best meets system requirements.

Attenuation

Attenuation is the reduction of signal strength or light power over the length of the light-carrying medium. Fiber attenuation is measured in decibels per kilometer (dB/km).

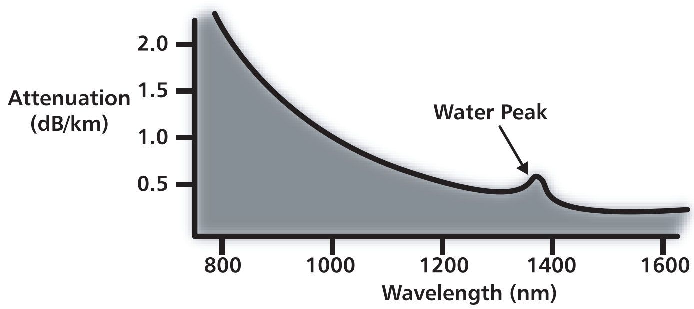
Optical fiber offers superior performance over other transmission media because it combines high bandwidth with low attenuation. This allows signals to be transmitted over longer distances while using fewer regenerators or amplifiers, thus reducing cost and improving signal reliability.

Attenuation of an optical signal varies as a function of wavelength (see Figure 9). Attenuation is very low, as compared to other transmission media (i.e., copper, coaxial cable, etc.), with a typical value of 0.35 dB/km at 1300 nm. Attenuation at 1550 nm is even lower with a typical value of 0.25 dB/km. This gives an optical signal, transmitted through fiber, the ability to travel more than 100 km without regeneration or amplification.

Attenuation is caused by several different factors, but scattering and absorption primarily cause it.

The scattering of light from molecular level irregularities in the glass structure leads to the general shape of the attenuation curve (see Figure 9). Further attenuation is caused by light absorbed by residual materials, such as metals or water ions, within the fiber core and inner cladding. It is these water ions that cause the “water peak” region on the attenuation curve, typically around 1383 nm. The removal of water ions is of particular interest to fiber manufacturers as this “water peak” region has a broadening effect and contributes to attenuation loss for nearby wavelengths. Light leakage due to bending, splices, connectors, or other outside forces are other factors resulting in attenuation.

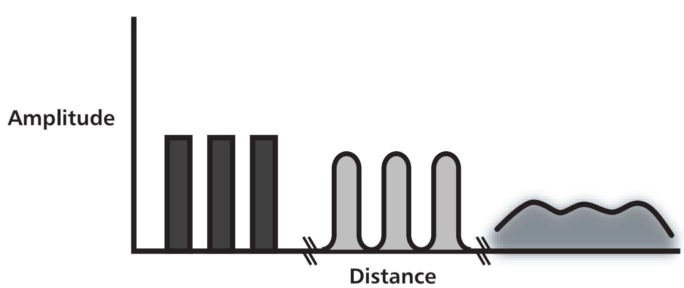
Figure 9. Typical Attenuation vs. Wavelength



Dispersion

Dispersion is the time distortion of an optical signal that results from the many discrete wavelength components traveling at different rates and typically result in pulse broadening (see Figure 10). In digital transmission, dispersion limits the maximum data rate, the maximum distance, or the information-carrying capacity of a singlemode fiber link. In analog transmission, dispersion can cause a waveform to become significantly distorted and can result in unacceptable levels of composite second-order distortion (CSO).

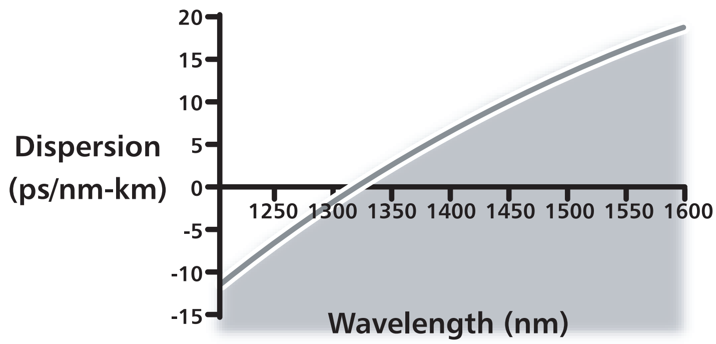
Figure 10. Impact of Dispersion



Dispersion vs. Wavelength

Fiber dispersion varies with wavelength and is controlled by fiber design (see Figure 11). The wavelength at which dispersion equals zero is called the zero-dispersion wavelength. This is the wavelength at which fiber has its maximum information-carrying capacity. For standard singlemode fibers, this is in the region of 1310 nm. The units for dispersion are also shown in Figure 11.

Figure 11. Typical Dispersion vs. Wavelength Curve



Chromatic dispersion consists of two kinds of dispersion. Material dispersion refers to the pulse spreading caused by the specific composition of the glass. Waveguide dispersion results from the light traveling in both the core and the inner cladding glasses at the same time but at slightly different speeds. The two types can be balanced to produce a wavelength of zero dispersion anywhere within the 1310 nm to 1650 nm operating window.

Transmission in the 1550 nm Window

Optical fibers also can be manufactured to have the zero dispersion wavelength in the 1550-nm region, which is also the point where silica-based fibers have inherently minimal attenuation. These fibers are referred to as dispersion-shifted fibers and are used in long-distance applications with high bit rates. For applications utilizing multiple wavelengths, it is undesirable to have the zero dispersion point within the operating wavelength range and fibers known as nonzero dispersion-shifted fiber (NZDSF) are most applicable. NZDSF fibers with large effective areas are used to obtain greater capacity transmission over longer distance than would be possible with standard singlemode fibers. These fibers are able to take advantage of the optical amplifier technology available in the 1530 to 1600+ nm operating window while mitigating nonlinear effects that can be troublesome at higher power levels.

For applications such as the interconnection of headends, delivery of programming to remote node sites, high-speed communication networks, and regional and metropolitan rings (used primarily for competitive access applications), NZDSF fiber can improve system reliability, increase capacity, and lower system costs.

Mode-Field Diameter

Mode-field diameter (MFD) describes the size of the light-carrying portion of the fiber. This region includes the fiber core as well as a small portion of the surrounding cladding glass. MFD is an important parameter for determining a fiber's resistance to bend-induced loss and can affect splice loss as well. MFD, rather than core diameter, is the functional parameter that determines optical performance when a fiber is coupled to a light source, connectorized, spliced, or bent. It is a function of wavelength, core diameter, and the refractive-index difference between the core and the cladding. These last two are fiber design and manufacturing parameters.

Cutoff Wavelength

Cutoff wavelength is the wavelength above which a singlemode fiber supports and propagates only one mode of light. An optical fiber that is singlemoded at a particular wavelength may have two or more modes at wavelengths lower than the cutoff wavelength.

The effective cutoff wavelength of a fiber is dependent on the length of fiber and its deployment and the longer the fiber, the lower the effective cutoff wavelength. Or the smaller the bend radius of a loop of the fiber is, the lower the effective cutoff wavelength will be. If a fiber is bent in a loop, the cutoff is lowered.

Environmental Performance

While cable design and construction play a key role in environmental performance, optimum system performance requires the user to specify fiber that will operate without undue loss from microbending.

Microbends are small-scale perturbations along the fiber axis, the amplitude of which are on the order of microns. These distortions can cause light to leak out of a fiber. Microbending may be induced at very cold temperatures because the glass has a different coefficient of thermal expansion from the coating and cabling materials. At low temperatures, the coating and cable become more rigid and may contract more than the glass. Consequently, enough load may be exerted on the glass to cause microbends. Coating and cabling materials are selected by manufacturers to minimize loss due to microbending.

Specification Examples of Uncabled Fiber

To ensure that a cabled fiber provides the best performance for a specific application, it is important to work with an optical fiber–cable supplier to specify the fiber parameters just reviewed as well as the geometric characteristics that provide the consistency necessary for acceptable splicing and connectorizing.

Splicers and Connectors

As optical fiber moves closer to the customer, where cable lengths are shorter and cables have higher fiber counts, the need for joining fibers becomes greater. Splicing and connectorizing play a critical role both in the cost of installation and in system performance.

The object of splicing and connectorizing is to precisely match the core of one optical fiber with that of another in order to produce a smooth junction through which light signals can continue without alteration or interruption.

There are two ways that fibers are joined:

- splices, which form permanent connections between fibers in the system
- connectors, which provide remateable connections, typically at termination points

Fusion Splicing

Fusion splicing provides a fast, reliable, low-loss, fiber-to-fiber connection by creating a homogenous joint between the two fiber ends. The fibers are melted or fused together by heating the fiber ends, typically using an electric arc. Fusion splices provide a high-quality joint with the lowest loss (in the range of 0.01 dB to 0.10 dB for singlemode fibers) and are practically nonreflective.

Mechanical Splicing

Mechanical splicing is an alternative method of making a permanent connection between fibers. In the past, the disadvantages of mechanical splicing have been slightly higher losses, less-reliable performance, and a cost associated with each splice. However, advances in the technology have significantly improved performance. System operators typically use mechanical splicing for emergency restoration because it is fast, inexpensive, and easy. (Mechanical splice losses typically range from 0.05–0.2 dB for singlemode fiber.)

Section 2: Fiber Optic Interconnect Product Offerings

Connectors

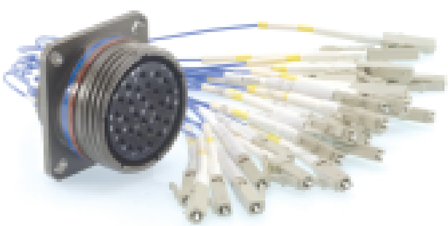
Connectors are used in applications where flexibility is required in routing an optical signal from lasers to receivers, wherever reconfiguration is necessary, and in terminating cables. These remateable connections simplify system reconfigurations to meet changing customer requirements. There are two broad categories of connectors. The first, is a broad collection of connectors intended for commercial applications. Typically these are single channel (simplex) or dual channel (duplex) solutions. With the on-going development of smaller interconnect solutions many of the historical “standards” are nearly gone from use. The latest commercial optical interconnects are based upon Telcordia’s GR-326 requirements for “Small Form Factor” optical interconnects. The most popular optical interconnect today is the LC developed by Lucent and the MU developed by NTT. Both of these interconnects utilize a 1.25mm ceramic ferrule and sleeve physical contact interface. The smaller form factor ceramic is proving to deliver significantly lower insertion losses and in a more consistent performance across varied environments.

The second category of optical interconnects is a centered around a collection of more specialized solutions intended for severe environments typically found in outdoor applications, military/aerospace or heavy industrial locations. The foundation for military optical interconnect is the Mil-T-29504 specification. Various configurations of products have resulted from that specification for various interconnect solutions. Typically, the optical termini defined by that specification are used in mixed mode (electrical/optical) interconnects.

ITT Fiber Optic interconnect solutions;

2.1 Ground Tactical: FOMC / ITAC (MIL-PRF-83526)

The Cannon FOMC and ITAC connector system is offered in two different connector styles with both being considered a field tactical connector and was primarily designed to meet the needs of the military and commercial customers who require a harsh environmental multi-fiber field connector. Both the FOMC and ITAC connectors combines features which provide the user with a connector that will withstand rough handling and weather extremes with features such as elastomeric cable and interface sealing, scoop proof interface to prevent optical contact damage, removable front insert for easy optical contact cleaning, anodized shell finish and a attached dust cap. Both connector series utilize an industry standard physical contact ceramic ferrule assembly, and have an internal fiber chamber for extra fiber storage which eliminates tensile loads form being applied to the terminated fiber and allows for contact re-termination. Another feature is the hermaphroditic design which enables multiple FOMC or ITAC plug or receptacle assemblies to be daisy-chained together in the field. For additional information for FOMC please see page 24 and for ITAC page 28.



2.2 FOHC

The Cannon FOHC contact is offered in 2 different alignment styles, a metallic body with ceramic zirconia ferrule tip and a patented metallic body with jewel tip. Both contact series conforms to the MIL-T-29504 fiber optic termini specification and fits into any size 16 cavity with no modification to the connector. The FOHC contact is designed for use with the standard size 16 insertion/extraction tool, and both the pin and socket end faces have easy access for cleaning. The FOHC precision ceramic tip offers superior coupling performance and a simplified termination process. Ceramic zirconia tips more accurately center the fiber within the contact body. During the mating engagement there is a rugged alignment sleeve which precisely aligns the mating contacts together for optimum performance. The jewel ferrule alignment system provides precise alignment regardless of fiber size, accommodates fiber tolerances, eliminates the requirement for a minimum end gap, and allows for spring loading of contacts. For additional information please see page 32.

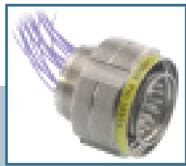
2.3 PHD

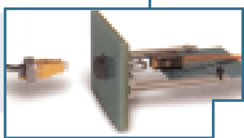
ITT provides flexibility in the optical system design with the Cannon PHD line of high density optical interconnects. The PHD connector system's open architecture delivers high performance, density and serviceability in a flexible and scalable product configuration. The PHD optical interconnect provides solutions for the Telecommunication, Automotive, Commercial Aircraft, Data Communications, Industrial, Medical and Military Electronic industries.

The Cannon PHD interconnect is based around the industry standard 1.25 mm ceramic ferrule technology which allows rapid system integration and a common terminus platform for singlemode and multimode optical fiber solutions. The contact systems is offered in both a size 22 and size 16 contact assembly configuration which provides a cable termination range form 250 micron up to a 2 millimeter outer jacket along with different I.D. ferrule sizes to accommodate a large range of fiber types. Both the size 22 and size 16 contact assemblies utilize the same ceramic zirconia ferrule which meets the GR-326 endface geometry compliance. The PHD system assures the industry's highest and most stable performance for any multi-channel interconnect, resulting in the lowest insertion loss value, less channel to channel variance and a higher return loss of any fiber optic interconnect in the industry. For additional information please see page 38.

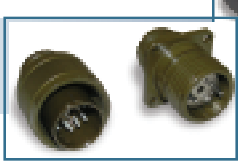
2.4 NGCON

The NGCON connector system is the new standard for military fiber optic interconnect applications. ITT's design will be qualified to the yet to be released NGCON Specification and will provide a high-performance fiber optic interconnect solution for air, sea and space applications. This new connector system was designed with innovations including genderless contacts and high density packaging combined with proven technology and features from connector standards 28876 and 38999. For additional information please see page 61.









	AIRBORNE		GROUND		NAVAL	
	Exposed	Non-Exposed	Exposed	Non-Exposed	Exposed	Non-Exposed
PHD 38999	P [1]	R	P [1]	R	P [1]	R
PHD Panel Mount		R		R		R
PHD Backplane		R		R		R
PHD Super LC		R		R		R
D-Sub Specials Hybrid Connector (Electrical & F.O.) w/custom F.O. inserts & PHD termini		R		R		R
Trident Specials Hybrid Connector (Electrical & F.O.) w/custom F.O. inserts & PHD termini		R		R		R
Rack & Panel Specials Hybrid Connector (Electrical & F.O.) w/custom F.O. inserts & PHD termini		R		R		R
D38999 Hybrid Connector (Electrical & F.O.) w/ FOHC or 29504 Termini	P [2]	R	P [2]	R	P [2]	R
Rack & Panel Specials Hybrid Connector (Electrical & F.O.) w/custom F.O. inserts & 29504 termini		R		R		R
M38999 Physical Contact	P [2]	R	P [2]	R	P [2]	R
M38999 Expanded Beam	P [2]	R	P [2]	R	P [2]	R
FOMC			R	R	P	P
NGCON	P [3]	P [3]	P [3]	P [3]	R [3]	R [3]
ITAC			R [3]	R [3]		

R = Recommended Application

P = Possible Application

(grey box) = Not recommended for this application

1 = Required for this application: Environmental sealed backshell, Mated condition or environmental sealed dust cap. Consult factory for recommended plating requirements

2 = Required for this application: Environmental sealed backshell. Consult factory for recommended plating requirements

3 = Product Release Scheduled for 2007 Q2

	ITT SPECIFICATIONS														
	Product Configuration						Fiber / Cable Compatibility				Environmental				
Connector Product Offering	Shell Size / Type	Contact Size	Contact Ferrule O.D.	Channel Count	Plating (Connector)	Strain Relief System	Fiber Type (MM /SM)	Max. Fiber Buffer / Coating Dia.	Max. Diameter (Simplex / Sub-Cable)	Cable Construction Type	Operating Temperature Range	Mating Durability	Vibrations	Shock	
PHD 38999	11 thru 25 Circular	22		Standard Min. 4 Max 72	Nickel OD Cad	Sealed Backshell - Used with Breakout / Distribution cable types	Single Mode -9/125 Multi Mode - 50/125, 62.5/125, 100/140 For Large Core / Plastic Fiber consult factory for compatibility requirements	900um	SM 1.1mm MM -1.2mm	Buffered Fiber, Cable-Simplex & Multi Channel Distribution Breakout	-65C to +165C		PHD variation of MIL-DTL-38999	PHD variation of MIL-DTL-38999	
		16		Standard Min. 2 Max 36				900um	2 mm						
PHD Panel Mount	Rectangular	22		Standard Min. 8 Max 64	Nickel	Backshell - Used with Breakout / Distribution cable types		900um	SM 1.1mm MM -1.2mm		-65C to +125C	500	EIA/TIA-455-11 test condition VI-D	EIA/TIA-455-14 test condition A	
PHD Backplane		22		8	Robust Design - Nickel	None		900um	SM 1.1mm MM -1.2mm	Buffered Fiber or Simplex Cable	-55C to +85C		Test Pending	Test Pending	
PHD Super LC Simplex / Duplex	Rectangular LC Simplex / Duplex	16	1.25 mm	1-Simplex 2-Duplex	NA	Boot		900um	2 mm	Buffered Fiber, Simplex & Zip Cord Duplex Cable	-65C to +125C	500	Test Pending	Test Pending	SM M
D-Sub Specials Hybrid Connector (Electrical & F.O.) w/custom F.O. inserts & PHD termini	Rectangular	22			Cadmium Tin Zinc	Specials Only Consult Factory		900um	NA	Buffered Fiber or Simplex Cable	-55C to +125C	500	MIL-DTL-24308	MIL-DTL-24308	
Trident Specials Hybrid Connector (Electrical & F.O.) w/custom F.O. inserts & PHD termini	Circular	22		Consult Factory	NA			900um	NA		-55C to +105C	500	Consult Factory	Consult Factory	
Rack & Panel Specials Hybrid Connector (Electrical & F.O.) w/custom F.O. inserts & PHD termini	Rectangular	22			Nickel OD Cad	Specials Only		900um	SM 1.1mm MM -1.2mm		-65C to +125C	500	MIL-C-81659	MIL-C-81659	
		16						900um	2 mm			500			
D38999 Hybrid Connector (Electrical & F.O.) w/ FOHC or 29504 Termini	11 thru 25 Circular	16		37	Nickel OD Cad	Sealed Backshell - Used with Breakout / Distribution cable types		900um	2 mm			500	MIL-DTL-38999	MIL-DTL-38999	S M
Rack & Panel Specials Hybrid Connector (Electrical & F.O.) w/custom F.O. inserts & 29504 termini	Rectangular	16		Consult Factory	Nickel OD Cad	None		900um	2 mm	Buffered Fiber, Cable-Simplex & Multi Channel Distribution / Breakout	-65C to +200C Cable / Contact dependent	500	MIL-C-81659	MIL-C-81659	
M38999 Physical Contact	Circular			Consult Factory	Nickel OD Cad	Sealed Backshell - Used with Breakout / Distribution cable types		900um	2 mm			500	MIL-DTL-38999	MIL-DTL-38999	
M38999 Expanded Beam	Circular		2.50 mm	Consult Factory	Nickel OD Cad	Sealed Backshell - Used with Breakout / Distribution cable types		900um	2 mm			500	MIL-DTL-38999	MIL-DTL-38999	
FOMC	Circular	16		Standard Min. 2 Max 12	Hard Black Anodize	Sealed Backshell - Used with Breakout / Distribution cable types		900um	2 mm		-65C to +150C	200	Consult Factory	Consult Factory	M
NGCON	Circular	16		Standard Min. 2 Max 36	Nickel OD Cad			900um	2 mm		-65C to +165C	500	MIL-PRF-Pending	MIL-PRF-Pending	M
TFOCA II	Circular	16		Standard Min. 2 Max 4	Hard Black Anodize			900um	2 mm		-65C to +165C	500	MIL-PRF-83526	MIL-PRF-83526	M

Compliance Notes

1 = Required Configuration: Environmental sealed backshell, mated condition or environmental sealed dust cap.

2 = Consult factory for recommended plating requirements

3 = Cable Dependent. Consult factory for Mil-spec, Ground Tactical & Avionic Cable offering

4 = Compliant with mating assist feature (Coupling Nut / Jackscrew)

Compliance Key

TBD = Consult Factory for specific configuration requirements

C = Compliant

▢ = Not recommended for this requirement

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Optical Performance				TYPICAL MILITARY/AEROSPACE REQUIREMENTS												
nsertion Loss (dB Max.)	Insertion Loss (dB Typical)	Return Loss (dB Min.)	Return Loss (dB Typical)	Insertion Force < 50 lbs	Mating Durability (>100 cycles)	Bend Life (repeated flexing)	Vibration Rigid body motion / >200Hz primary modes	Temperature -55 to +85 degrees C	Shock Drop, Handling, Etc.	Maintenance Removal and Installation	Humidity 5% non-condensing / 100% condensing	Cable Retraction System (Exposed)	Cable Retraction System (Non-Exposed)	Corrosion Resistance	Exposed Completely exposed to outside environment	Non-Exposed Cabin / Cabinet / etc (Environmentally Controlled)
				C 4	C	C 3	C	C	C	C	C	C 1	C	C 2	C 1	C
				C 4	C	C 3	C	C	C	C	C		C	C 2		C
				C	C	C 3	C	C	C	C	C			C 2		C
M tuned 0.3 MM-0.5	SM tuned 0.2 MM-0.3	SM-50 MM-20	SM-56 MM-25	C	C	C 3	C	C	C	C	C			C		C
				C	C	C 3	C	C	C	C	C		C	C 2		C
				C 4	C	C 3	C	C	C	C	C		C	C		C
				C	C	C 3	C	C	C	C	C			C 2		C
M-1.0 M-0.75	SM-0.6 MM-0.75	SM-50 MM-20	SM-55 MM-25	C 4	C	C 3	C	C	C	C	C	C 1	C	C 2	C 1	C
				C 4	C	C 3	C	C	C	C	C			C 2		C
Consult Factory				C 4	C	C 3	C	C	C	C	C	C 1	C	C 2	C 1	C
Consult Factory				C 4	C	C 3	C	C	C	C	C	C 1	C	C 2	C 1	C
MM-1.5	MM-1.0	MM-20	MM-25	C 4	C	C 3	C	C	C	C	C	C 1	C	C 2	C 1	C
MM-0.5	MM-0.3	MM-20	MM-25	C 4	C	C 3	C	C	C	C	C	C 1	C	C 2	C 1	C
MM-0.5	MM-0.3	MM-20	MM-25	C 4	C	C 3	C	C	C	C	C	C 1	C	C 2	C 1	C