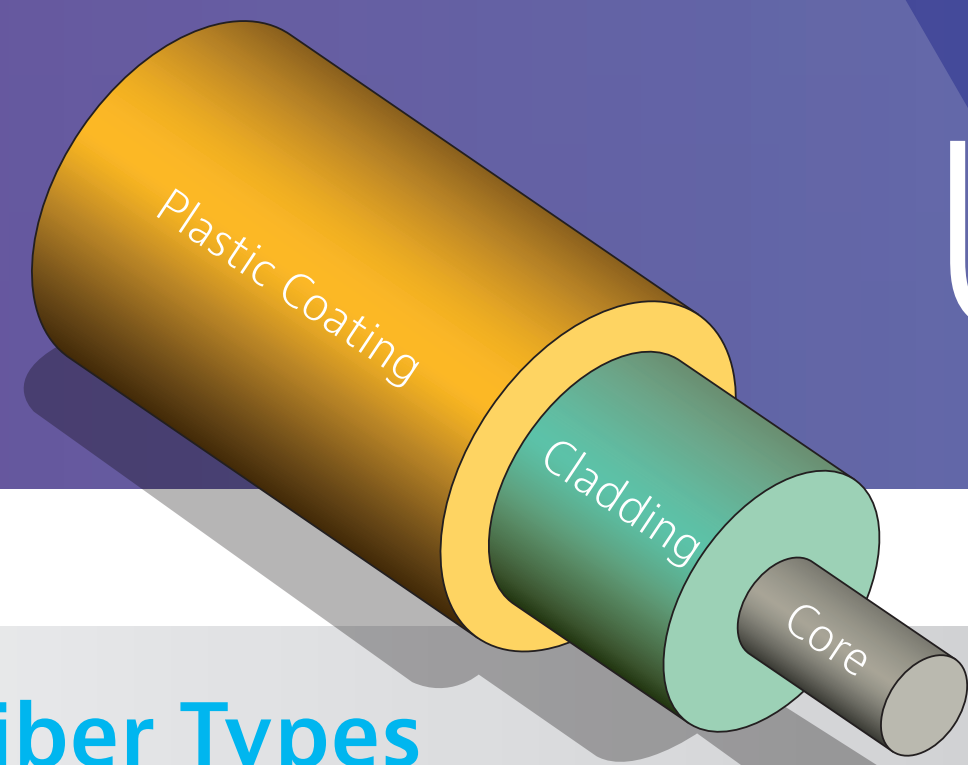


# Understanding Fiber Optics



## Optical Fiber Types

Main Type	Characteristics	Typical Dimensions	Lightwave Propagation	Index Profile
Single-mode	<ul style="list-style-type: none"> <li>Low attenuation</li> <li>1260 to 1640 nm transmission wavelengths</li> <li>Access/medium/long-haul networks (&gt;200 km)</li> <li>Nearly infinite bandwidth</li> </ul>			
Multimode (graded index)	<ul style="list-style-type: none"> <li>High attenuation</li> <li>850 to 1300 nm transmission wavelengths</li> <li>Local networks (&lt;2 km)</li> <li>Limited bandwidth</li> </ul>			

**Refractive index:** A measure of the speed of light in a material. The  $n_1$  and  $n_2$  are the respective refractive index of the cladding and the core.  $n_1 < n_2$  is the condition for the light to travel down the fiber.  
**Index profile:** Variations of the refractive index along a fiber diameter.

ITU Fiber Standard	Description	Applications
<b>G.651</b>	Characteristics of a 50/125 mm multimode-graded index optical fiber cable	Video and datacom in premises networks Up to 10 GE transmission in local area networks (up to 300 m) Wavelength coverage: 850 to 1300 nm
<b>G.652 Class A/B</b> <b>G.652 Class C/D</b>	Characteristics of single-mode optical fiber and cable	From access to long-haul networks; supports high bit rate transmission (>10 G, 10 E, and on); suitable for DWDM and CWDM systems Wavelength coverage: 1260 to 1625 nm
<b>G.655 Class C</b> <b>G.655 Class D</b> <b>G.655 Class E</b>	Characteristics of non-zero-dispersion-shifted single-mode optical fiber and cable	Transmission applications at high bit rates for STM-64/OC-192 (10 G) over longer distances; suitable for STM-256/OC-568 (40 G); supports DWDM transmission applications in the C-L bands Wavelength coverage: 1550 to 1625 nm
<b>G.657 Class A</b> <b>G.657 Class B</b>	Characteristics of bending loss-insensitive single-mode optical fiber and cable for access networks	Support optimized access network installation with very short bending radii applied in fiber management systems and particularly for indoor and outdoor installation, particularly in FTx networks Wavelength coverage: 1260 to 1625 nm

## Typical Fiber Cables

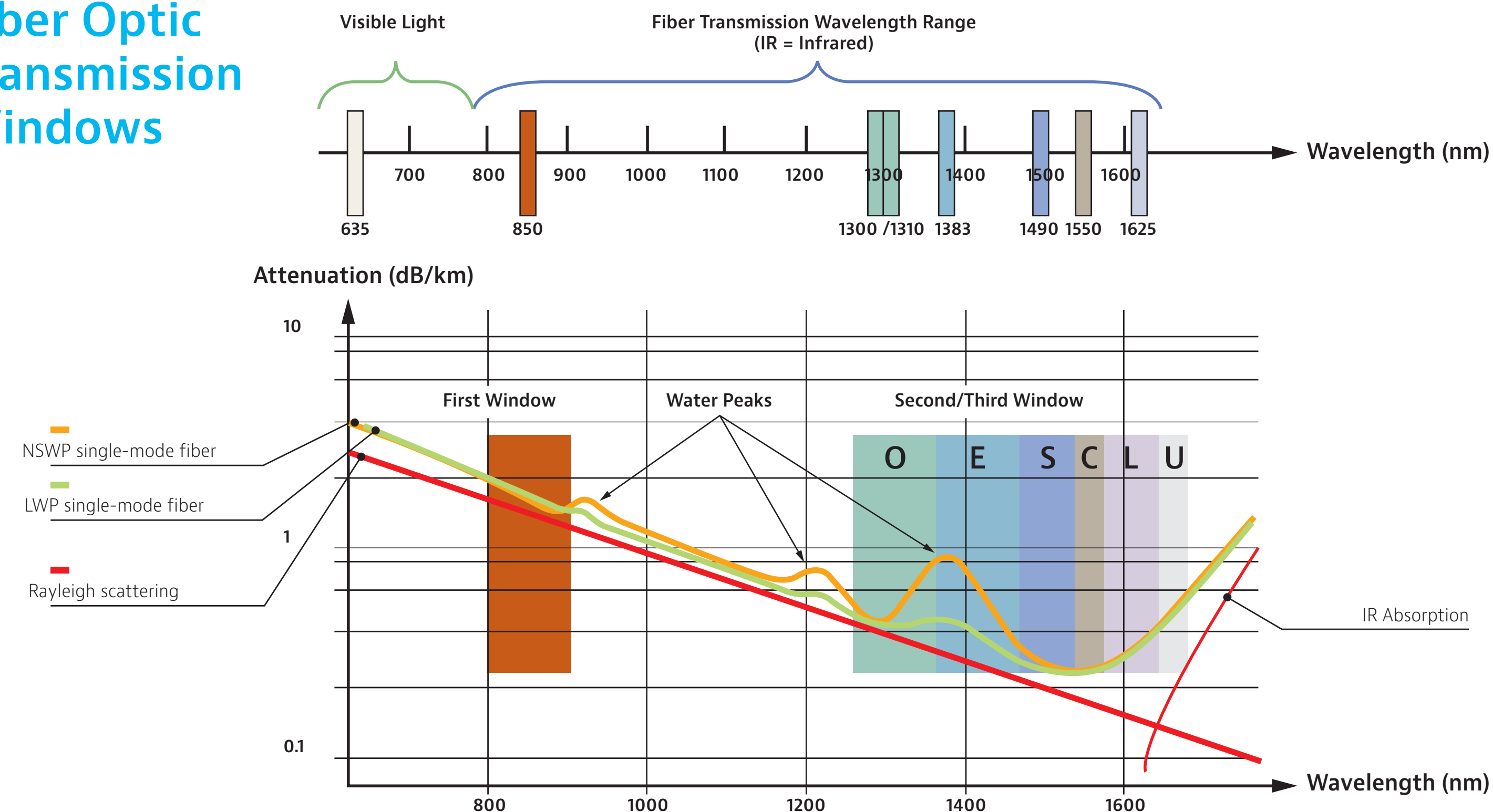
A cable consists of optical fibers surrounded by materials that provide them with mechanical and environmental protection

**Tight Buffered Tube Cables (Indoor)**  
Applications: Computer rooms, telecommunications central offices, tunnels and confined areas, and riser shafts. A tight buffered tube cable can hold 1 to 12 fibers per tube (up to 200 fibers in one cable).

**Loose Tube Cables (Outdoor)**  
Applications: Building interconnections, telecommunications, data trunk, long haul networks, and ducts between buildings. For applications requiring moisture and weather resistance. Loose tube cable can hold 1 to 12 fibers per tube (up to 200 fibers in one cable).

**Ribbon Fiber Cables**  
Typical applications: equipment interconnect, high-speed data transfer, premises network. Ribbon cables can hold 204 fibers in a 0.5-inch cable. This picture shows a 3000 fiber underground cable.

## Fiber Optic Transmission Windows



Band	Description	Wavelength Range
<b>O</b>	Original (second window)	1260 to 1360 nm
<b>E</b>	Extended	1360 to 1460 nm
<b>S</b>	Short wavelengths	1460 to 1530 nm
<b>C</b>	Conventional ("erbium window")	1530 to 1565 nm
<b>L</b>	Long wavelengths	1565 to 1625 nm
<b>U</b>	Ultra-long wavelengths	1625 to 1675 nm

### Attenuation results from various scattering and absorption mechanisms and is wavelength-dependent.

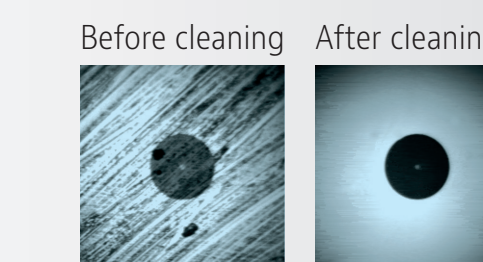
- Single-mode optical fibers operate over a wide range of wavelengths, therefore, the attenuation measurement is performed as a function of wavelength, typically between 1200 nm and 1625 nm.
- Fiber optic transmission uses the three optical windows (850, 1300, 1550 nm) provided by the attenuation characteristics of the silica fibers.
- Also, 635 nm light is used for visible fault location.
- Remote fiber testing uses a wavelength of 1625 nm or above to avoid disturbing traffic.

**Rayleigh scattering:** light energy is scattered in all directions causing loss  
**NSWP:** nonsuppressed water peak  
**LWP:** low water peak (for example, G.652.D fiber)

## Optical Connector

Connector Types*	Name	Applications
	FC-PC / FC-APC	Datacom, telecommunication, CATV
	SC-PC / SC-APC	Datacom, telecommunication, CATV, LAN
	E2000-PC / E2000-APC (Ferrule diameter : 1.25 mm)	Datacom, telecommunication, CATV, LAN
	LC-PC / LC-APC (Ferrule diameter : 1.25 mm)	High-density interconnection, datacom, telecommunication, CATV
	ST-PC	Inter-/intra-building, security, Navy, datacom, LAN
	MU-PC / MU-APC	Datacom, telecommunication, CATV
	MTP-MPO (ribbon fiber connectors)	Data center, inter/intra-building, LAN
	OptiTap®-PC / OptiTap®-APC	Outdoor FTx telecommunication

\* Nonexhaustive list



### Optical Connection Inspection

It is very important to clean connectors. A dirty connector will dramatically increase the power loss. Inspect your connector before and after cleaning using a videoscope.

## Optical Transmission

### Optical Loss Budget

Consider network topology and equipment specifications when installing a fiber network. One major parameter to measure is optical loss budget, or end-to-end optical link loss. Consider the source, detector, and optical transmission line when calculating the optical loss budget of a fiber link.

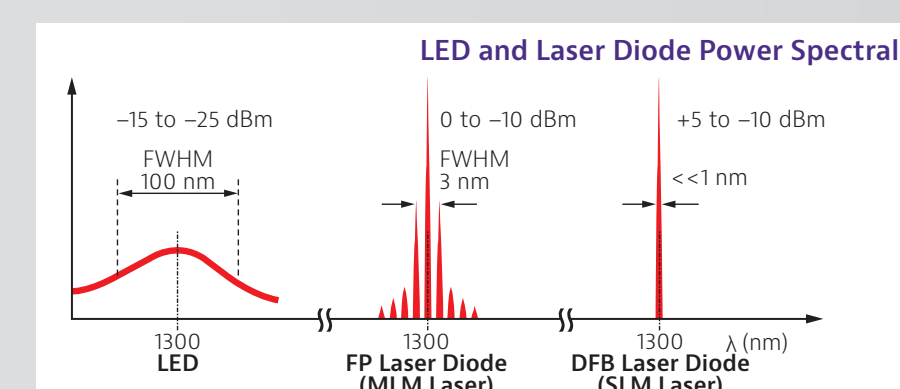
Example of a typical single-mode system  
 (1) Average transmitter (Tx) output optical power: **0 dBm**  
 (2) Minimum receiver (Rx) sensitivity: **-20 dBm**  
 (1) - (2) Maximum optical loss budget: **20 dB**



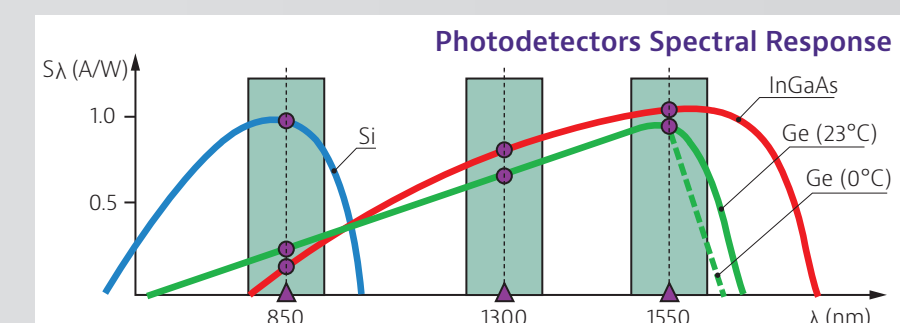
Optical loss budget must consider both link loss and system power margins to allow for the effects of environment, aging, and eventual repairs.

Use the typical values for various components to calculate link loss budgets.

- A** Total connector Loss = 0.5 dB x number of connector pairs
- B** Total fiber Loss = loss per km x fiber distance  
 1310 nm = 0.35 dB/km  
 1550 nm = 0.2 dB/km
- C** Total splice Loss = 0.1 dB x number of splices
- D** Total other components loss = loss x number of components  
 Mechanical splice = 0.5 dB  
 1:2 splitter = 3.5 dB  
 1:32 splitter = 17 dB



Fiber type used and the source characteristics limit system performance. The narrower the source diode spectral bandwidth, the higher the possible system frequency bandwidth/bit rate.  
**LED:** Short-haul and low bit rate (LAN networks) systems that use multimode fibers.  
**Laser Diode:** Long-haul and high bit rate systems that use single-mode fibers. Multilongitudinal mode (MLM) lasers, also known as Fabry-Perot (FP) lasers and single longitudinal mode (SLM) or distributed feedback (DFB) lasers are used for these applications.



**Si:** Silicon for applications in the visible light range (400 to 1000 nm)  
**Ge:** Germanium for applications in optical windows (750 to 1600 nm)  
**InGaAs:** Indium gallium arsenide for applications in optical windows (>1000 nm)

### Measurement Units : Watts, dB, or dBm

Absolute Power (mW)	Absolute Power (dBm)
1000	+30
100	+20
10	+10
5	+7
1	0
0.5	-3
0.1	-10
0.01	-20
0.001	-30
0.0001	-40

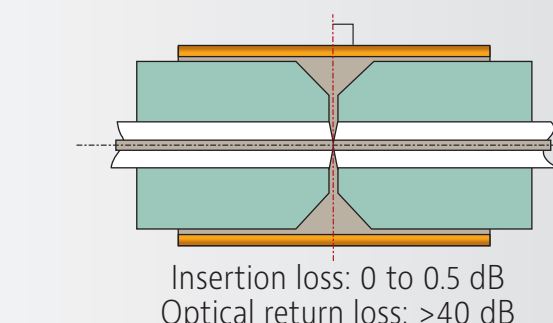
  

Loss (dB)	Power (%)
-0.10	2
-0.20	5
-0.35	8
-1	20
-3	50
-6	75
-10	90
-20	99

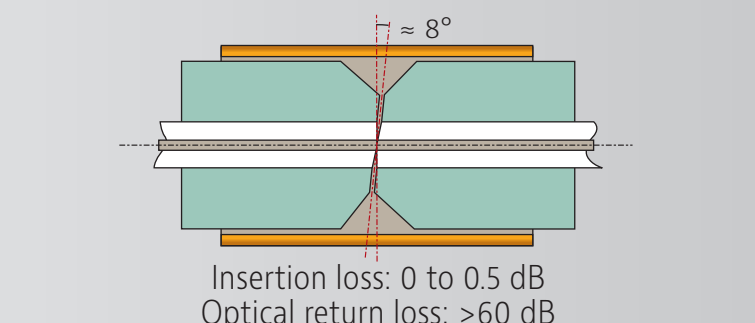
**dB:** quantify gain or loss  
 $dB = 10 \log \frac{P_1}{P_2}$  ( $P_1$  and  $P_2$  expressed in watts)

**dBm:** specify absolute power levels  
 $P(dBm) = 10 \log \frac{P}{1mW}$  ( $P$  expressed in mW)

### Physical Contact (PC) Connector



### Angled Physical Contact (APC) Connector



**Insertion loss (IL):** Loss in transmitted signal power resulting from the insertion of a component in an optical fiber link.  
**Optical return loss (ORL):** Ratio of the reflected power to the incident power from a fiber optic link or system, expressed as a positive value.

### Connector Mating

