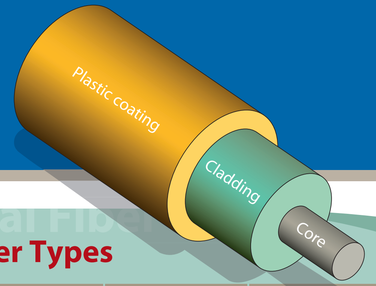
Understanding Fiber Optics



Optical Fiber Types

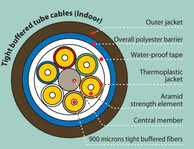
Main type	Characteristics	Typical dimensions	Lightwave propagation	Index Profile
Singlemode	- Low attenuation - 1260 to 1640 nm transmission wavelengths - Access/medium/long haul networks (>200km) - Nearly infinite bandwidth	8µm to 12µm / 125µm / 250 to 900µm	n1 = 1.457 n2 = 1.471	
Multimode (graded index)	- High attenuation - 850 to 1300 nm transmission wavelengths - Local networks (<2 km) - Limited bandwidth	50µm 62.5µm / 125µm / 250 to 900µm	n1 = 1.540 n2 = 1.540 to 1.562	

Refractive index: *A measure of the speed of light in a material. n1 and n2 are the respective refractive index of the cladding and the core. n1<n2 is the condition for the light to travel down the fiber.*
Index profile: *Variations of the refractive index along a fiber diameter.*

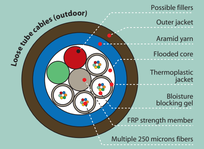
ITU Fiber Standard	Description	Applications
G.651	Characteristics of a 50/125 mm multimode graded index optical fibre cable.	Video and Datacom in premises networks. Up to 10 GigE transmission in local area networks (up to 300 m). Wavelength coverage: 850 to 1300 nm
G.652 Class A/B **G.652 Class C/D**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

Typical fiber cables

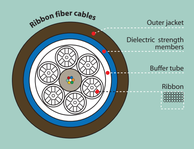
A cable is an assembly of optical fibers with materials providing mechanical and environmental protection of the optical fibers



Applications: Computer rooms, telecommunications central offices, tunnel and confined areas, riser shafts.
Tight buffered tube cable can hold from 1 to 12 fibers per tube (up to 200 fibers in one cable).

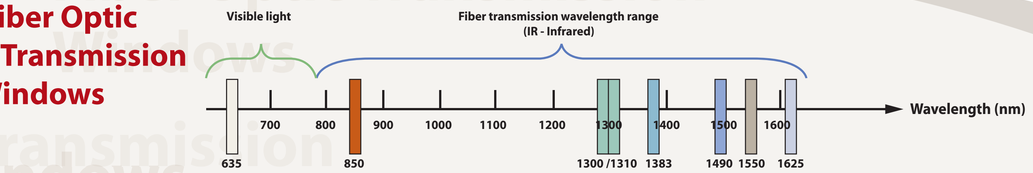


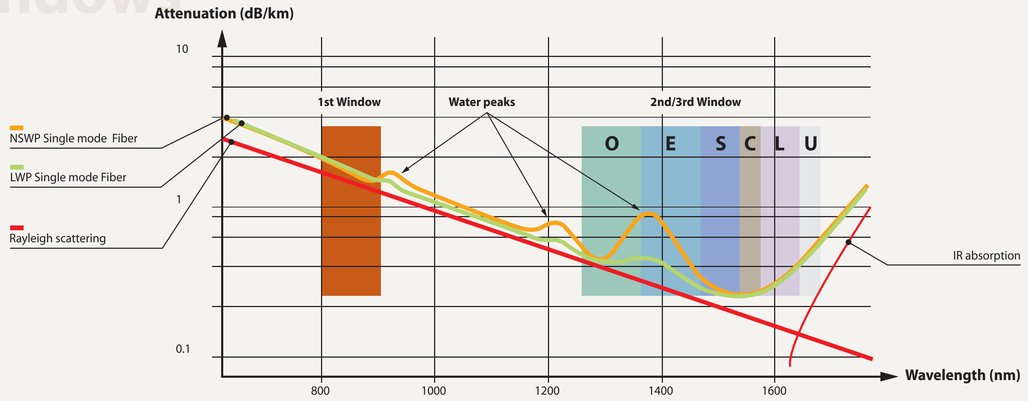
Applications: Building interconnections, telecommunications and, data trunk, long haul networks, ducts between buildings.
Applications requiring moisture and weather resistant. Loose tube cable can hold from 1 to 12 fibers per tube (up to 200 fibers in one cable).



Typical applications: equipment interconnect, high speed data transfer, premise 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
O	Original (2nd Window)	1260 to 1360 nm
E	Extended	1360 to 1460 nm
S	Short Wavelengths	1460 to 1530 nm
C	Conventional ("erbium window")	1530 to 1565 nm
L	Long wavelenghts	1565 to 1625 nm
U	Ultralong wavelengths	1625 to 1675 nm

Attenuation is the result of a variety of scattering and absorption mechanisms, and is wavelength dependent.

- Since singlemode optical fibers are designed to operate over a wide range of wavelengths, the attenuation measurement is performed as a function of wavelength, typically between 1200 nm and 1625 nm.
- Fiber optic transmission makes use of the three optical windows (850,1300, 1550 nm) that are given by the attenuation characteristics of the silica fibers.
- Also, 635 nm light is used for visible fault location.
- For remote fiber testing a wavelength of 1625nm or above is used to not disturb the traffic.

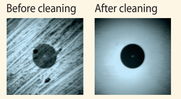
Rayleigh scattering: *light energy is scattered in all directions causing loss.*
NSWP: *Non Suppressed Water Peak.*
LWP: *Low Water Peak (ex: G.652.D fiber).*

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 : 1.25mm)	Telecommunication, Datacom, CATV, LAN
	LC-PC / LC-APC (Ferrule diameter : 1.25mm)	High density interconnection, Datacom, telecommunication, CATV
	ST-PC	Inter-/Intra-building, Security, Navy, Datacom, LAN
	MU-PC / MU-APC	Datacom, Telecommunication, CATV
	MT-RJ (Ribbon fiber)	Tatacom, LAN
	Biconic	LAN, Datacom, Medical instrumentation, Remote, sensing, Telemetry, CATV
	DIN-PC / DIN-APC	Datacom, Telecommunication, CATV

** Non exhaustive list*

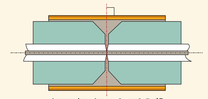
Before cleaning / After cleaning



Optical Connection Inspection

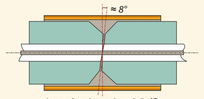
It is very important to clean connectors.
A dirty connector will dramatically increase the power loss !
Inspect your connector before and after cleaning using a videoscope.

Physical Contact (PC) Connector



Insertion Loss: 0 to 0.5 dB
Optical Return Loss: >40 dB

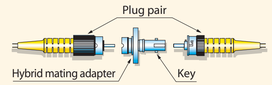
Angled Physical Contact (APC) Connector

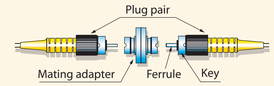


Insertion Loss: 0 to 0.5 dB
Optical Return Loss: >60 dB

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





Optical Transmission

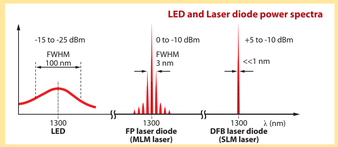
Optical Loss Budget

When installing a fiber network, network topology and equipment specifications must be considered. One of the major parameters requiring measurement is optical loss budget, or end-to-end optical link loss. When calculating the optical loss budget of a fiber link, the source, detector, and optical transmission line must be considered.

An example of a typical singlemode system could be:
(1) Average Transmitter (Tx) output optical power: **0 dBm**
(2) Minimum Receiver (Rx) sensitivity: **-20 dBm**
(1) – (2) Maximum optical loss budget: **20 dB**

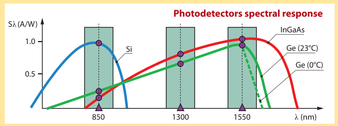
Optical loss budget should take into account both link loss and system power margins. These power margins cover allowances for the effects of environment, aging and eventual repairs.
In order to calculate link loss budgets, typical values of the different component are used.

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**



The type of fiber used and the characteristics of the source impose limits on system performance. The narrower the spectral bandwidth of the source diode, the higher the possible frequency bandwidth/bit rate of the system.
- LED: Short-haul and law bitrate (LAN networks) systems that use multi-mode fibers.
- Laser diode: Long-haul and high bitrate systems that use single mode fibers.

Multi-Longitudinal 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, applications in the visible light range (400 to 1000 nm)
Ge: Germanium, applications in optical windows (750 to 1600 nm)
InGaAs: Induim Galium Arsenide, application 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**
$dB = 10 \log \frac{P_1}{P_2}$ (P1 and P2 expressed in Watts)

dBm: specify absolute power levels
$P(dBm) = 10 \log \frac{P_1}{1mW}$ (P1 expressed in mW)

Note: Specifications, terms, and conditions are subject to change without notice.
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