CORNING

Glass Fibre Basics

Fibre Basic Training

Glass Fibre Basics

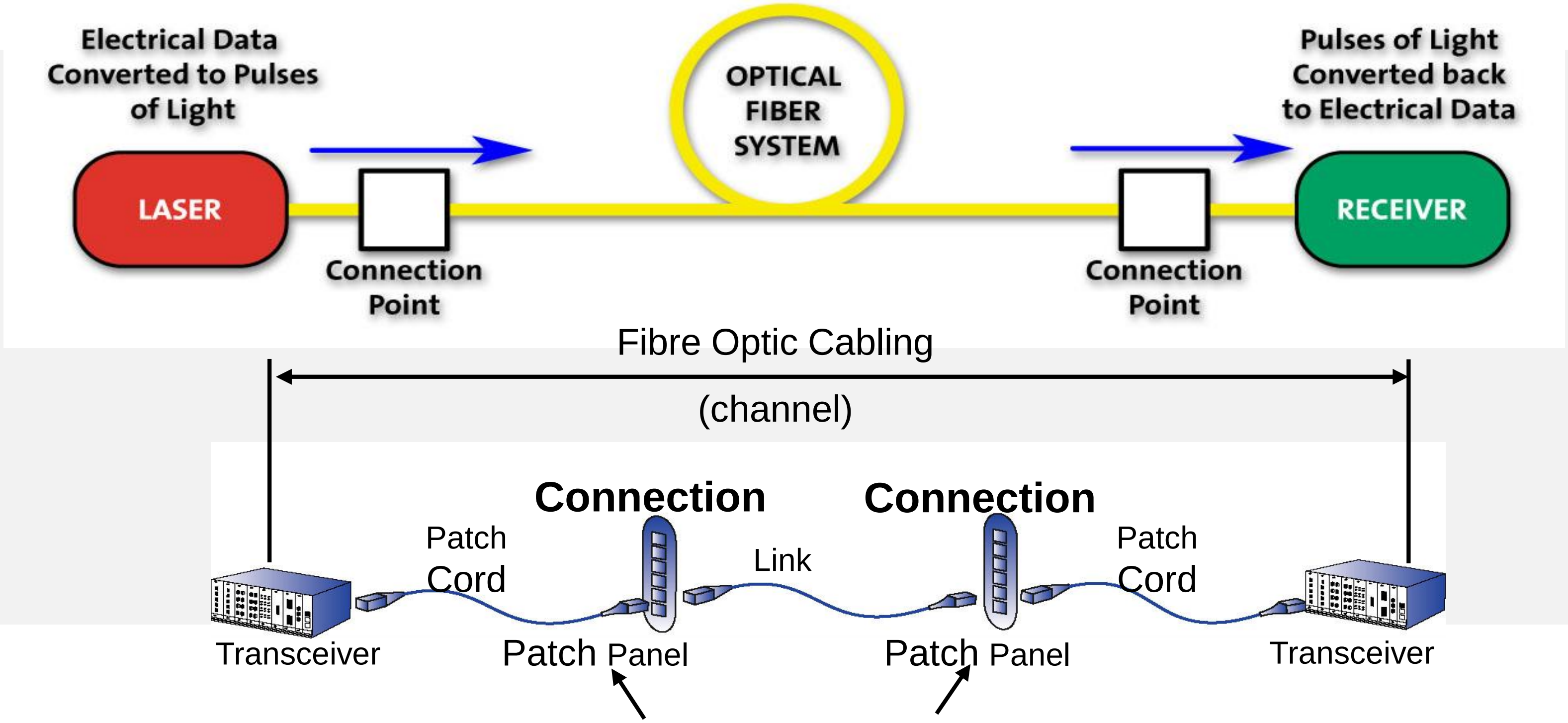
- Fibre Anatomy and the Difference Between Single- and Multimode Fibres
- The Making of an Optical Fibre
- Glass fibre physics
- Fibre parameters

Introduction to Fibre Optics

- Why we should care

Understanding basic fibre theory will help you understand your role in the system’s short-term and long-term reliability and performance.

Fibre Optic Systems
What it is



Structure of an Optical Fibre

CORE

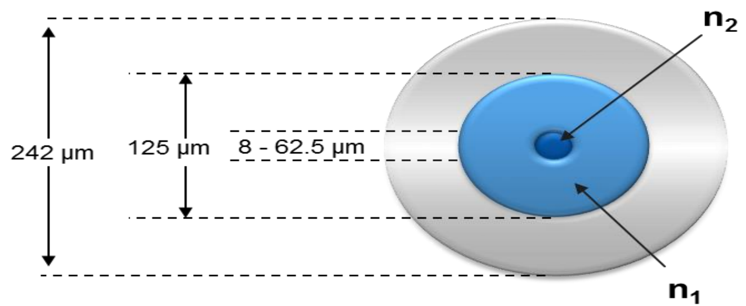
- Carries the light signals
- Silica and a dopant to raise index of refraction

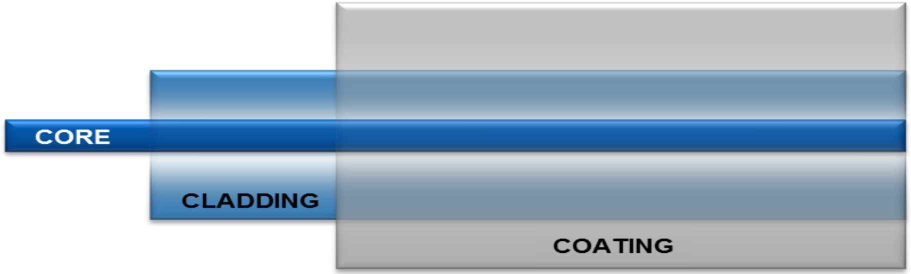
CLADDING

- Keeps the light in the core
- Pure silica

COATING

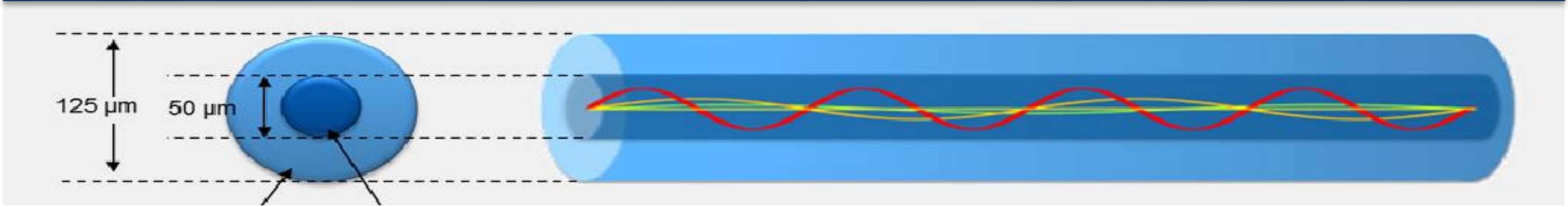
- Protects the glass
- Color coding
- Acrylate (plastic)



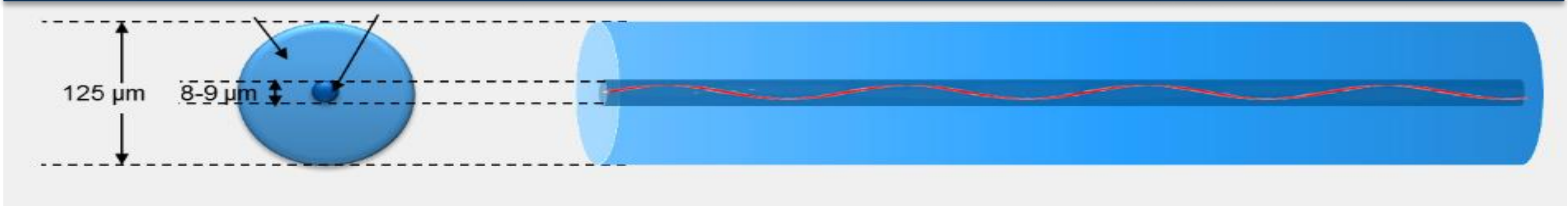


Light guiding - Modes

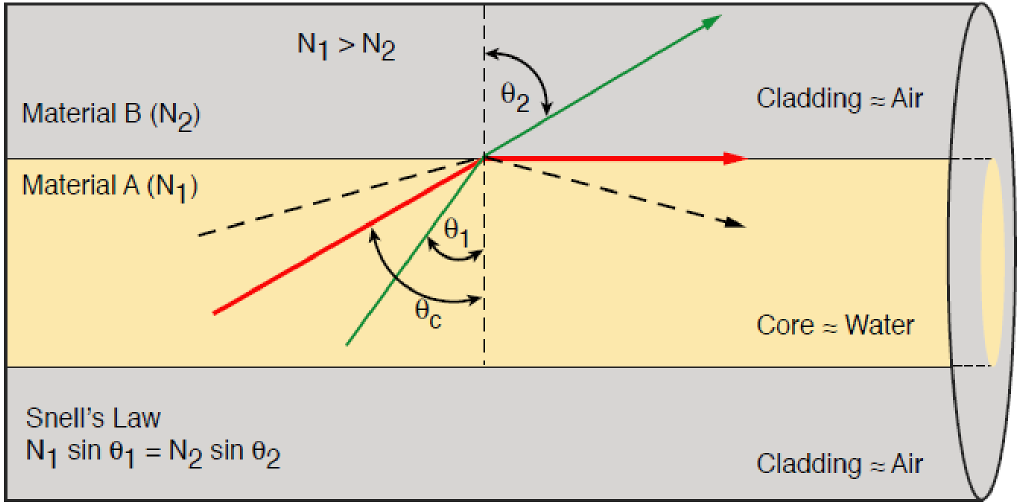
Multimode



Single-Mode



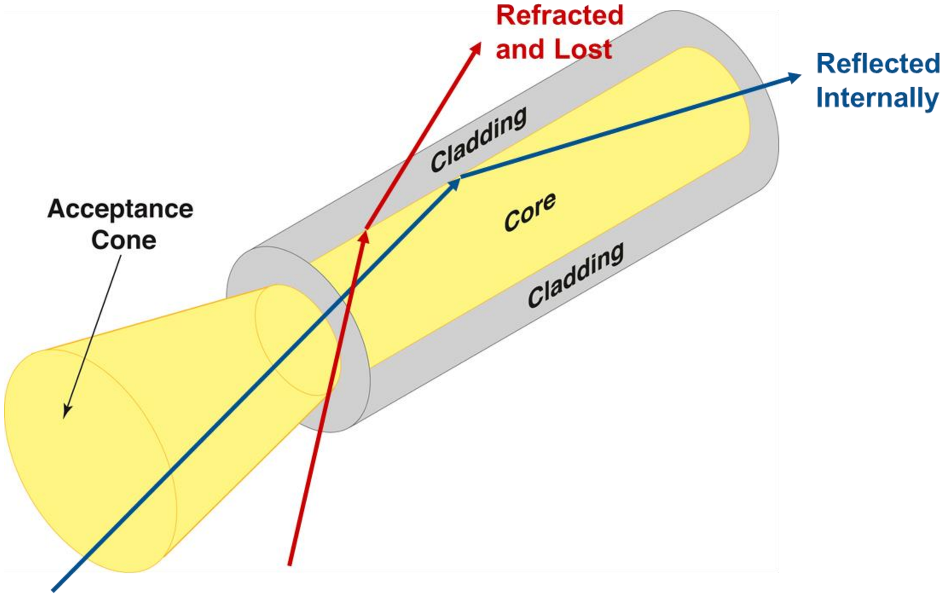
Requirement for Light Guiding



Total internal reflection @ Core-Cladding Interface

- The refrative index (N) of the core is greater than cladding
- The light will reflect inward or refract outward in the core

Total Internal Reflection



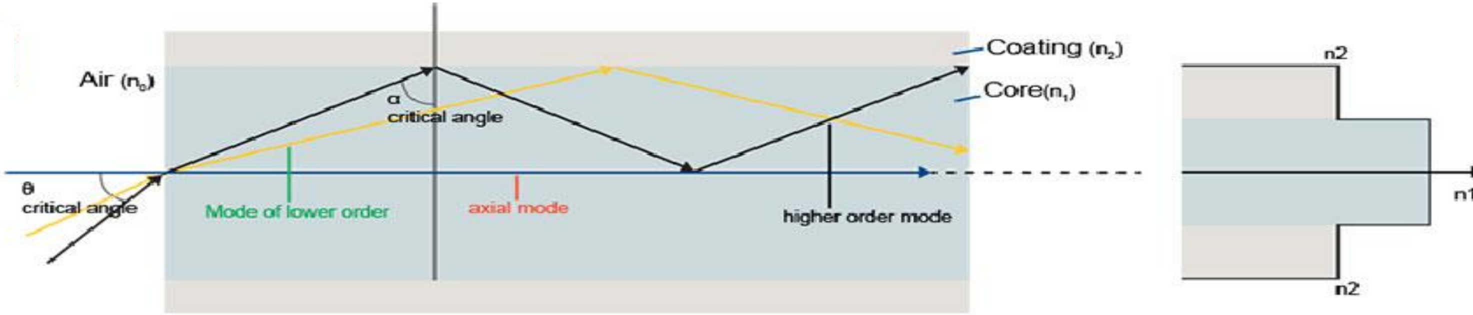
$$\sin\theta_C = \frac{n_{core}}{n_{cladding}}$$

For an optical fibre the following applies: n(core) > n(cladding) if the critical angle is not exceeded then there will be total internal reflection.

Multimode Fibres

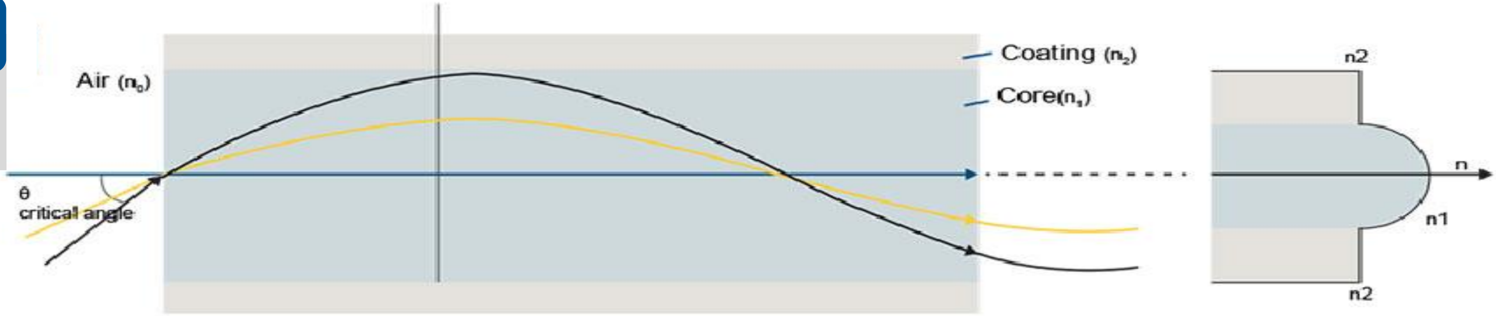
Step-index profile fibre

„Special Industry Fibres“



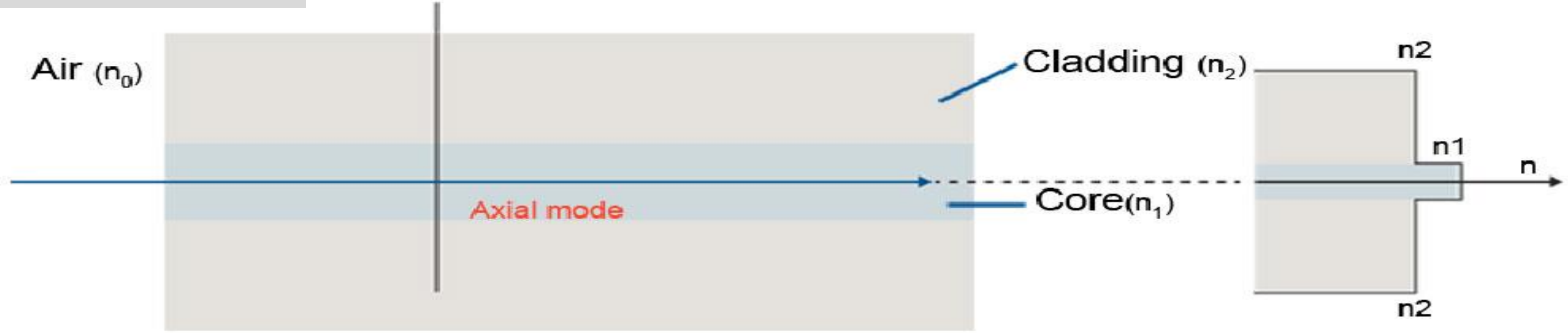
Graded-index profile fibre

LAN & DC Fibres
OM1,2,3,4 & 5



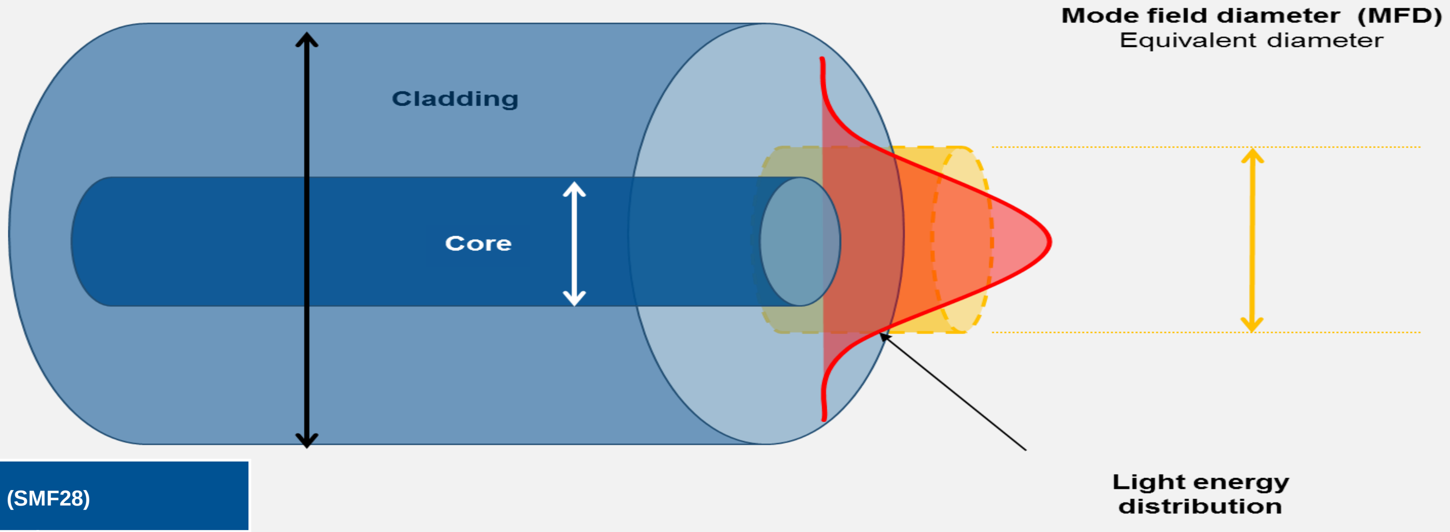
Single-Mode Fibre

Single-Mode Fibre
OS1, OS2 ITU G.652A,B,C,D ITU G.657A/B



Mode-Field Diameter (MFD)

A Significant Single-Mode Fibre Parameter



Example (SMF28)	
MFD	Core Diameter
1310 nm: 9,2 +/- 0,4 µm 1550 nm: 10,4 +/- 0,5 µm	8,2 µm

Best coupling of SMF if MFD is identical otherwise insertion loss occurs

Mode field diameter of ITU G.xxx singlemode fibers

ITU fiber standards		MFD [µm]				Wavelength
		Absolute Values		Nominal		
		min	max	min	max	[nm]
ITU G.	**652A**	8,00	10,10	8,6	9,5	1310
ITU G.	**652B**	8,00	10,10	8,6	9,5	1310
ITU G.	**652C**	8,00	10,10	8,6	9,5	1310
ITU G.	**652D**	8,00	10,10	8,6	9,5	1310
ITU G.	**654**	9,45	11,55	10,5	10,5	1550
ITU G.	**655**	7,20	12,10	8	11	1550
ITU G.	**657-A**	8,20	9,90	8,6	9,5	1310
ITU G.	**657-B**	5,90	9,90	6,3	9,5	1310

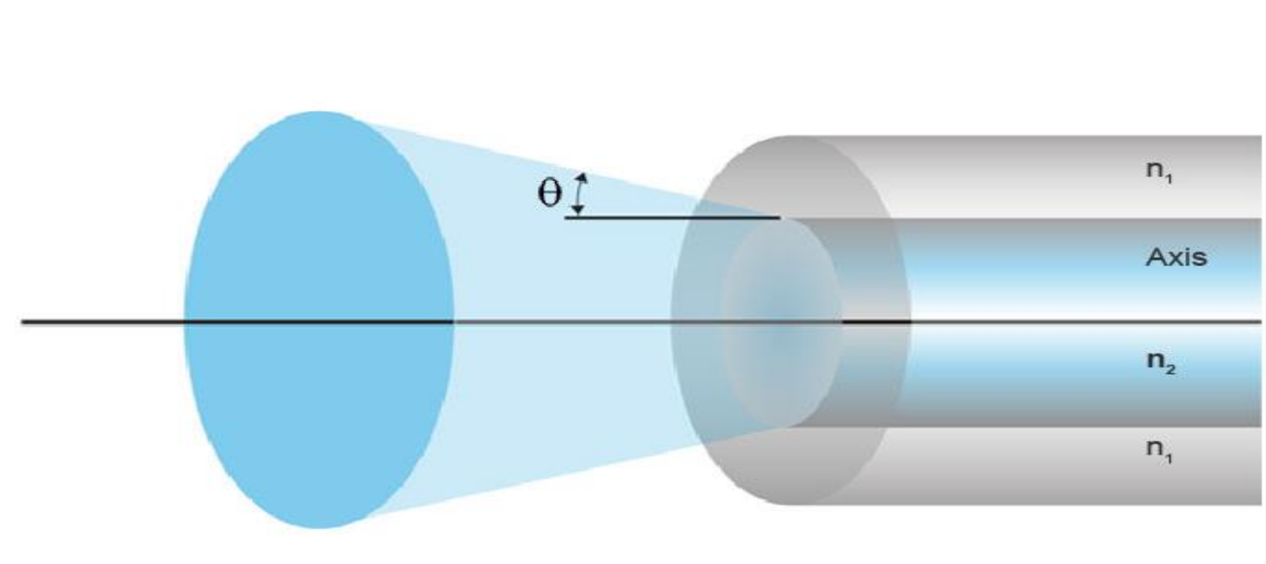
Source: ITU G.65X

Numerical Aperture (NA)

n_1 = Refractive index of the core
n_2 = Refractive index of the cladding
ϴ = Angle of acceptance

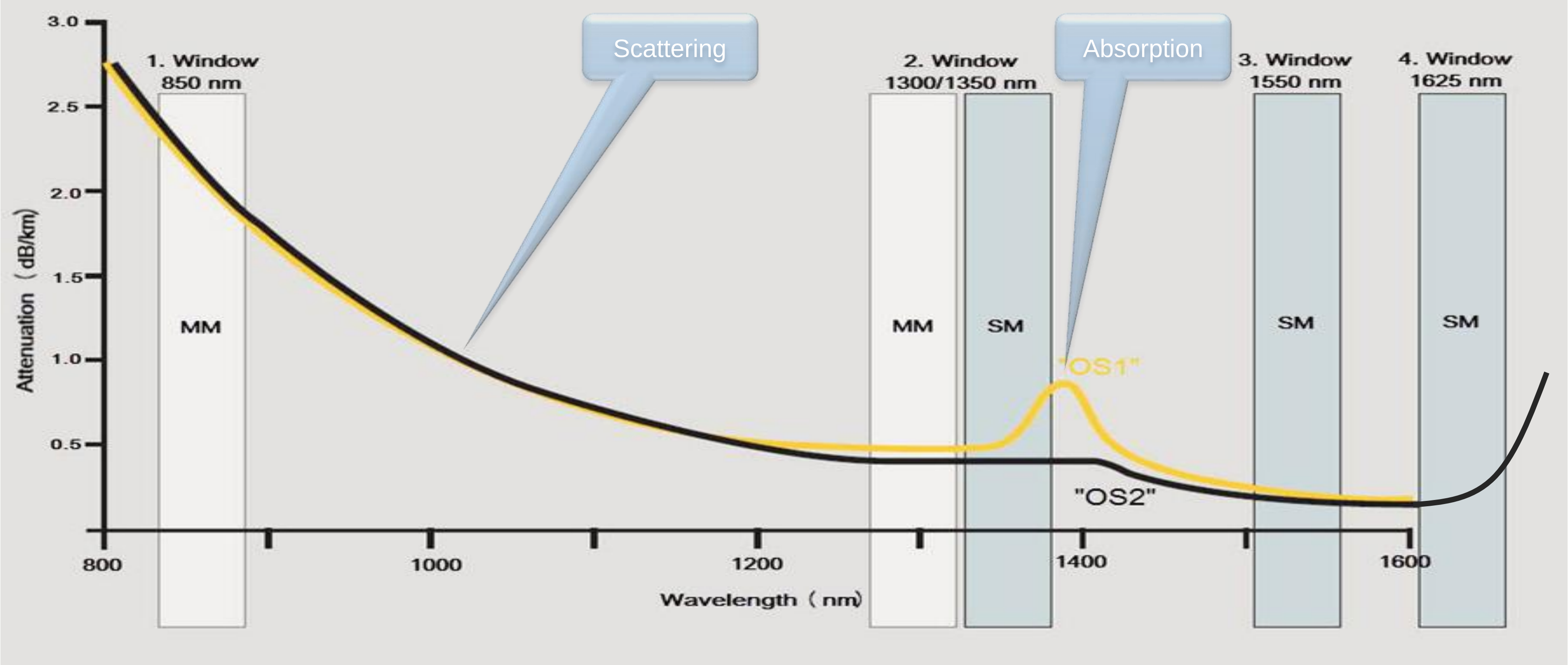
$$NA = \sin\theta = \sqrt{n2^2 - n1^2}$$

Examples:
OS1&2: NA 0,14 → ~ 8°
OM3&4: NA 0,2 → ~ 11,5°



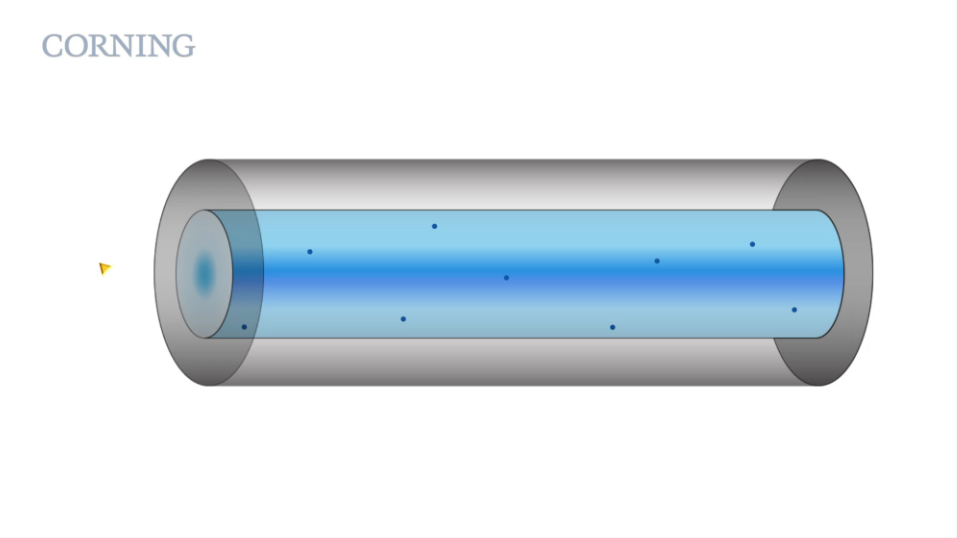
NA measures the range of angles of the rays that are injected into the fibre in a way that they will be totally internally reflected.

Spectral Attenuation Curve



Sources of Attenuation or Loss

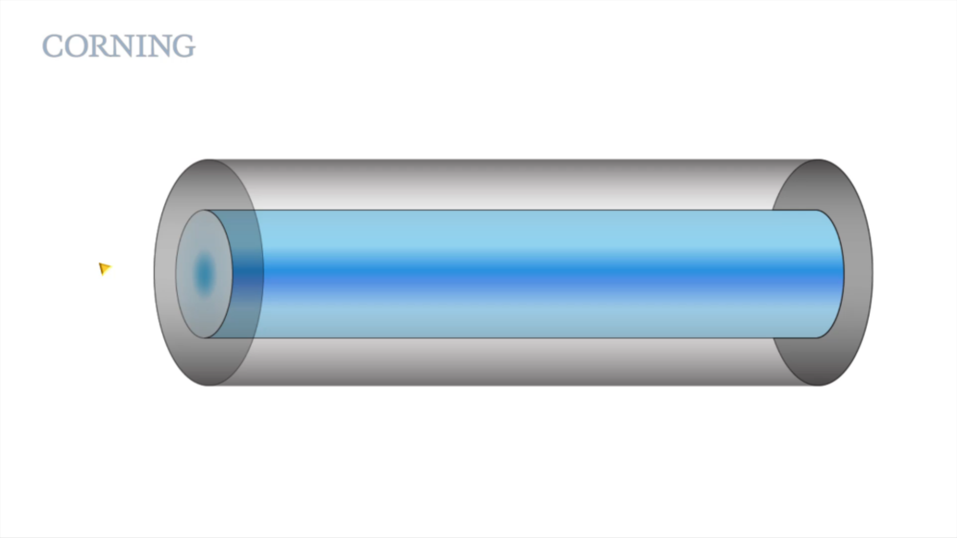
Scattering



In fibre optic transmissions, scattering is the loss of signal caused by the diffusion of a light beam, where the diffusion itself is caused by microscopic variations in the transmission medium. Scattering typically happens when a light signal hits an impurity in the fibre

Sources of Attenuation or Loss

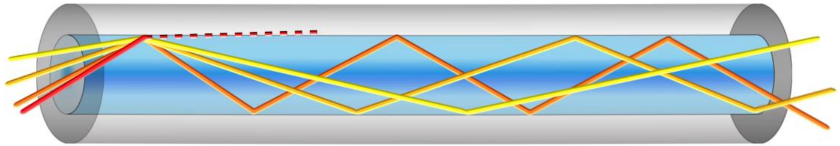
Absorption



Since light is a form of energy and since each form of energy interacts with matter, a certain portion of the energy is transferred to the material through which the light propagates

Sources of Attenuation or Loss

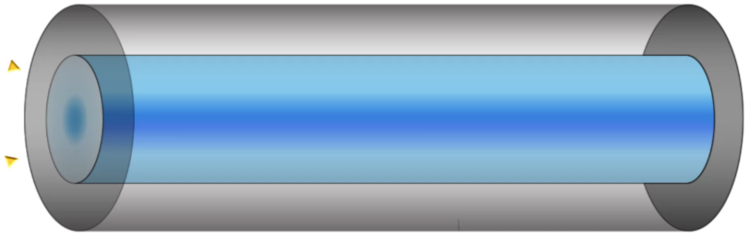
Macrobend



Macrobend is a large visible bend in the optical fibre that can cause extrinsic attenuation, a reduction of optical power in the glass.

Sources of Attenuation or Loss

Microbending



Microbend is an imperfection in the optical Fibre which was created during manufacturing. Microbending can cause extrinsic attenuation, a reduction of optical power in the glass. Unlike macrobending, the imperfection may not always be visible.

ClearCurve Demo Video

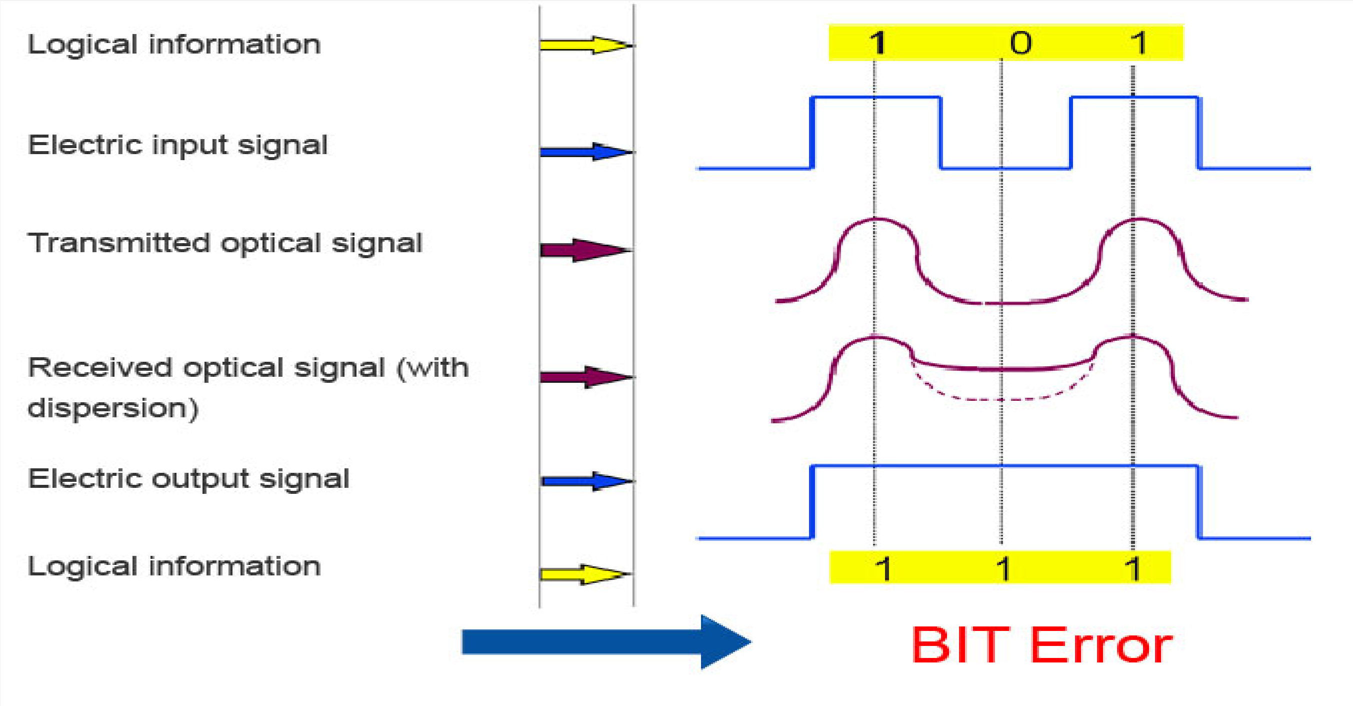
Principles of Transmission
Refractive Index

Medium	Refractive index	Speed of Light
Vacuum	1.0	300 km/s
Air	1.0003	299,70 km/s
Water	1.33	225,41 km/s
Cladding	1.46	205,34 km/s
Core	1.48	202,56 km/s

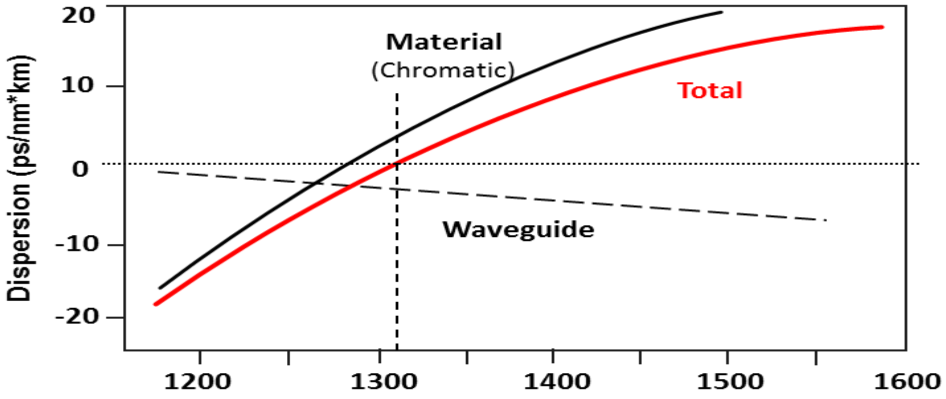
$$\text{Refractive index “n”} = \frac{\text{Speed of light in vacuum “c”}}{\text{Speed in medium “v”}}$$

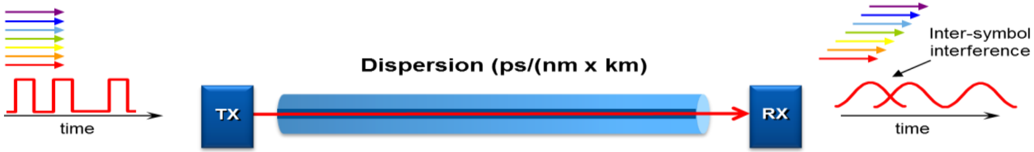
Dispersion – Effects on the signal

Affect the Transmission Bandwidth Quality



Dispersion



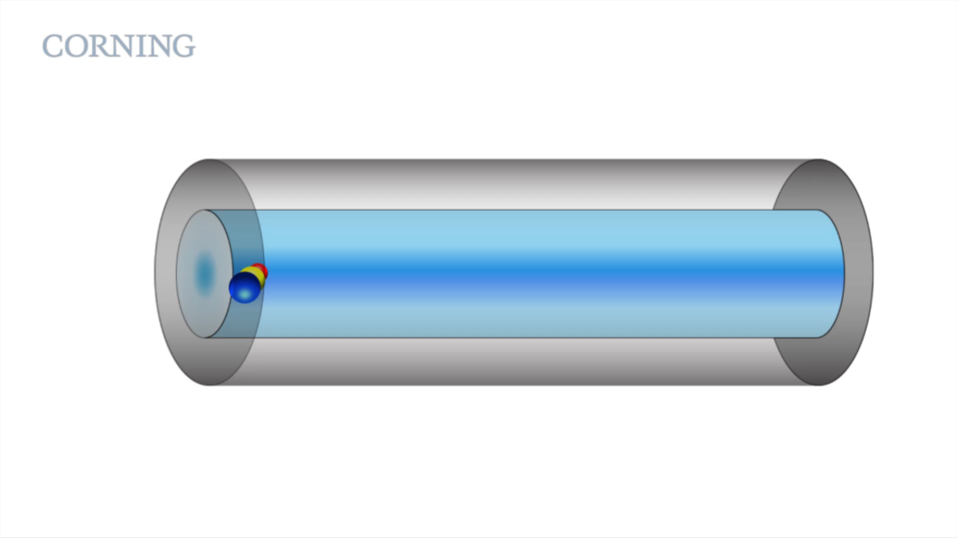


Dispersion is the broadening of a signal pulse over distance.

- It limits the speed or carrying capacity of the Fibre over a given distance before it has to be compensated for or regenerated
- It is expressed in ps/(nm*km)
- There are 3 types of dispersion:
  - Material (Chromatic) dispersion
  - Waveguide dispersion
  - Polarization Mode Dispersion (PMD)

Dispersion Types

Modal dispersion



- Modal dispersion occurs when the rays travel along multiple paths and have multiple path lengths. Since the rays do not travel the same distance, different rays will arrive at the end of the fibre at different times.
- Modal dispersion can therefore be described as path length dispersion.
- Modal dispersion is the biggest cause of dispersion. This type of dispersion occurs in multi-mode fibres, but not in single mode fibres.

System Performance Parameters

WAVELENGTH

- The Wavelength of light characterises its behaviour at the entry of a fibre and across a fibre
- Wavelength determined by the source (LASER)

ATTENUATION

- When light is transmitted through the fibre, attenuation occurs
- Attenuation changes with wavelength

DISPERSION

- When light is transmitted through the fibre, dispersion occurs, which determines the bandwidth of the fibre
- Dispersion changes with wavelength

Comparison single-mode versus multi-mode fibres

	Single-Mode Optical Fibre	Multi-Mode Optical Fibre
Application	✓ Campus Backbones ✓ WAN, MAN, subsea ✓ DWDM ✓ Amplfied fibre links ✓ FTTx ✓ DAS Networks	✓ Data Centers ✓ Local Area Networks ✓ Industrial Networks
Advantages	✓ Large bandwidth length product ✓ Highest communication bandwidth ✓ Lowest attenuation ✓ Lowest dispersion ✓ Many upgrade options ✓ Lowest fibre manufacturing cost	✓ Smaller bandwidth length product ✓ Lowest port cost ✓ Larger core size
Disadvantages	✓ Higher port cost ✓ Small core size	✓ Lengths limited by modal bandwidth ✓ Limited options for future upgrades ✓ Higher fibre manufacturing cost

Fibre Nomenclature – ISO/IEC 11801, EN 50173, TIA/EIA 568

Fibres with the following standards and dimensions are used in telecommunication technology:

Fibre Type / Core Dimensions	Core*	Cladding
Single-Mode, OS1 and OS2	9 µm	125 µm
Multimode OM1	62.5 µm	125 µm
Multimode OM2, OM3, OM4 and OM5	50 µm	125 µm

* For Single-Mode fibres, usually the MFD value at 1310 nm is used instead of the actual core diameter.

Fibre Nomenclature – Cross Reference

Fiber Core/Cladding size [µm]	Standard Overview Multimode Fibers			
	ITU	TIA/EIA	IEC 60793-2-10	ISO/IEC 11801
62.5/125	-	492AAAA	A1b	OM1
50/125	G651.1	492AAAC-A	A1a.1	OM2
50/125	G651.1	492AAAC-B	A1a.2	OM3
50/125	G651.1	492AAAD	A1a.3	OM4
50/125	G651.1	492AAAE	A1a.4	OM5

Type	IEC 60793-50	ITU	ISO/IEC 11801
Standard	B1.1	G.652.A/B	OS1
	B1.3	G.652.C/D	OS2
Bend insensitive	B6_a1	G.657.A1	OS1/2
	B6_a2	G.657.A2	
	B6_b2	G.657.B2	
	B6_b3	G.657.B3	

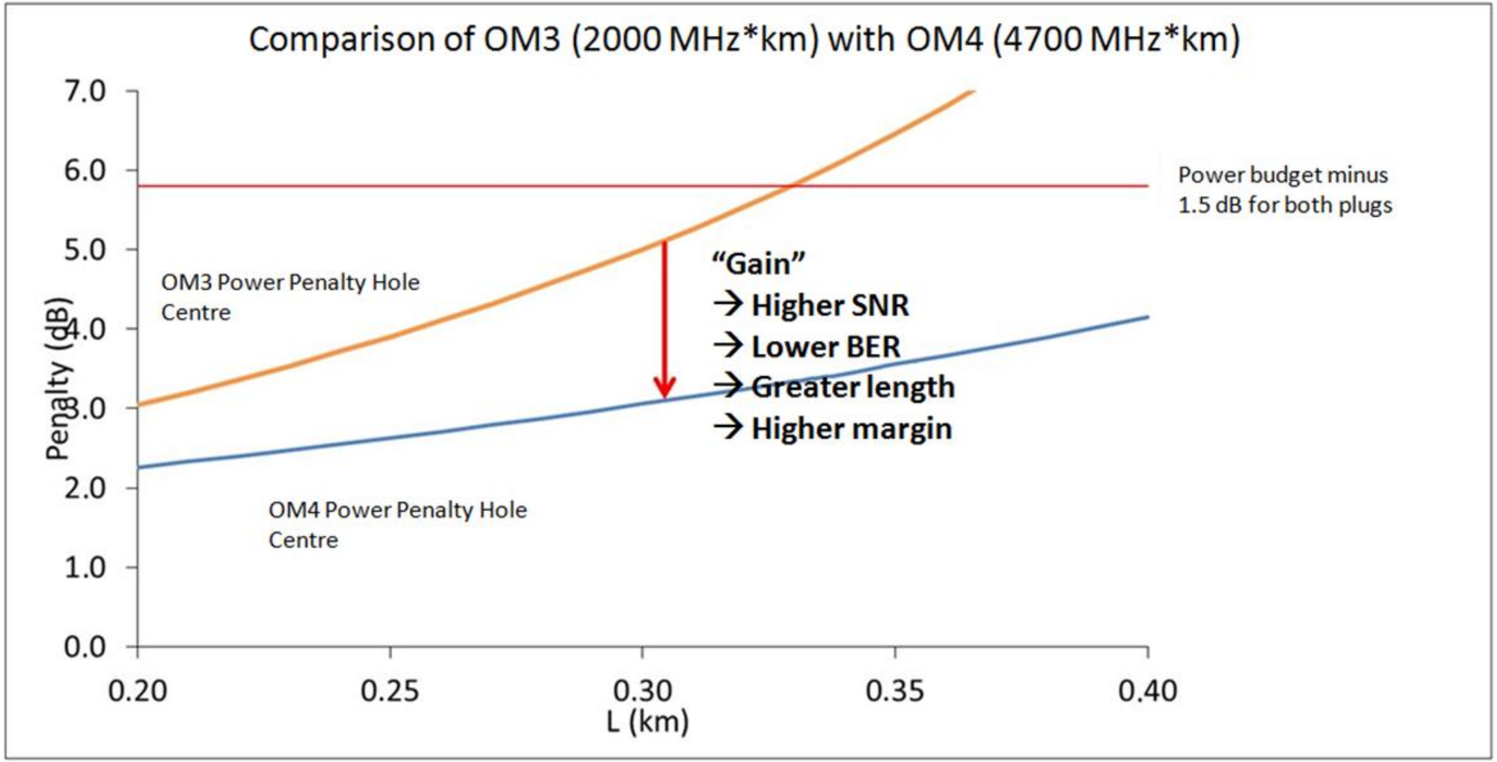
MM fibers characteristic

Corning Brand Name	OM1 InfiniCor300	OM2 ClearCurve OM2 Pretium 150	OM3 ClearCurve OM3 Pretium 300	OM4 ClearCurve OM4 Pretium 550
ITU Fiber type	N/A	G651.1	G651.1	G651.1
Cladding [um]	125.0 +/-2.0	125.0 +/-2.0	125.0 +/-2.0	125.0 +/-2.0
Core [um]	62.5 +/-2.5	50 +/-2.5	50 +/-2.5	50 +/-2.5
Atten @ 850nm [dB/km] (max)	≤3.1	≤2.8	≤2.8	≤2.8
Atten @ 1300nm [dB/km] (max)	≤0.8	≤1.0	≤1.0	≤1.0
10Gbps@850nm [m]	33	150	300	550 (with SFP+)
Macrobend Loss @850nm[dB] (7.5mm Dia)	N/A	≤0.2	≤0.2	≤0.2

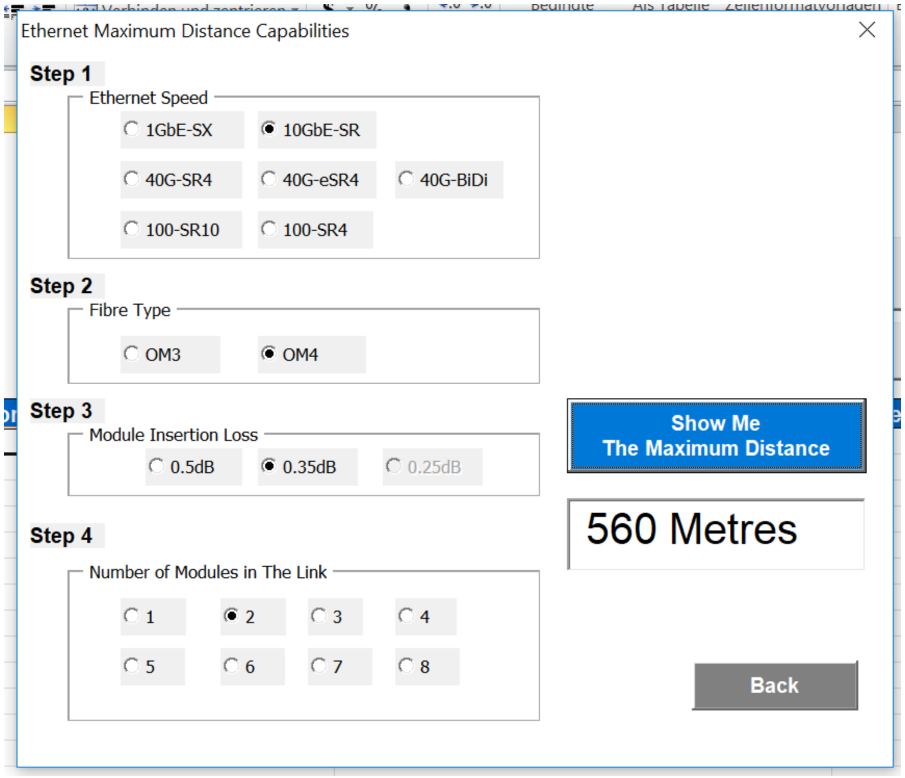
SM fibers characteristic

Corning Brand Name	OS2 SMF 28e+ E9	OS2 SMF 28e+ LL E9 LL	OS2 SMF 28e+ LL E9 ULL	LEAF E10	Ultra E9U	ClearCurve LBL E9CCR7.5	Clear Curve ZBL E9CCR5
ITU Fiber type	G652.(A,B,C,D)	G652.(A,B,C,D)	G652.(A,B,C,D)	G655.(A,B,C,D)	G657.A1	G657.A2/B2	G657.B3
Cladding [um]	125.0 +/-0.7	125.0 +/-0.7	125.0 +/-0.7	125.0 +/-0.7	125.0 +/-0.7	125.0 +/-0.7	125.0 +/-0.7
Core [um]	8.2	8.2	8.2	N/A	N/A	N/A	N/A
MFD @1310nm [um]	9.2 +/-0.4	9.2 +/-0.4	9.2 +/-0.4		9.2 +/-0.4	8.6 +/-0.4	8.6 +/-0.4
MFD @1550nm [um]	10.4 +/-0.5	10.4 +/-0.5	10.4 +/-0.5	9.2 to 10.0	10.4 +/-0.5	9.6+/-0.5	9.6+/-0.5
Atten @ 1310nm [dB/km] (max)	≤0.34	≤0.32	≤0.31	≤0.4	≤0.32	≤0.35	≤0.35
Atten @ 1550nm [dB/km] (max)	≤0.20	≤0.18	≤0.17	≤0.19	≤0.18	≤0.20	≤0.20
Atten @ 1625nm [dB/km] (max)	≤0.23	≤0.20	≤0.20	≤0.21	≤0.20	≤0.23	≤0.23
Dispersion @1550nm [ps/(nm*km)]	≤18.0	≤18.0	≤18.0	2.0 - 6.0 (@1530-1565nm)	≤18.0	≤18.0	≤18.0
Macrobend Loss @1550nm[dB] (5mm Dia)	N/A	N/A	N/A	N/A	N/A	N/A	≤0.1
Macrobend Loss @1550nm[dB] (7.5mm Dia)	N/A	N/A	N/A	N/A	N/A	≤0.4	N/A
Macrobend Loss @1550nm[dB] (10mm Dia)	N/A	N/A	N/A	N/A	≤0.5	N/A	N/A
Macrobend Loss @1550nm[dB] (32mm Dia)	≤0.03	≤0.03	≤0.03	≤0.5	≤0.03	≤0.03	≤0.03

Comparison of OM3 with OM4 (10GBASE-SR)



Corning De-rating Tables & BOM tool Derating Calculation



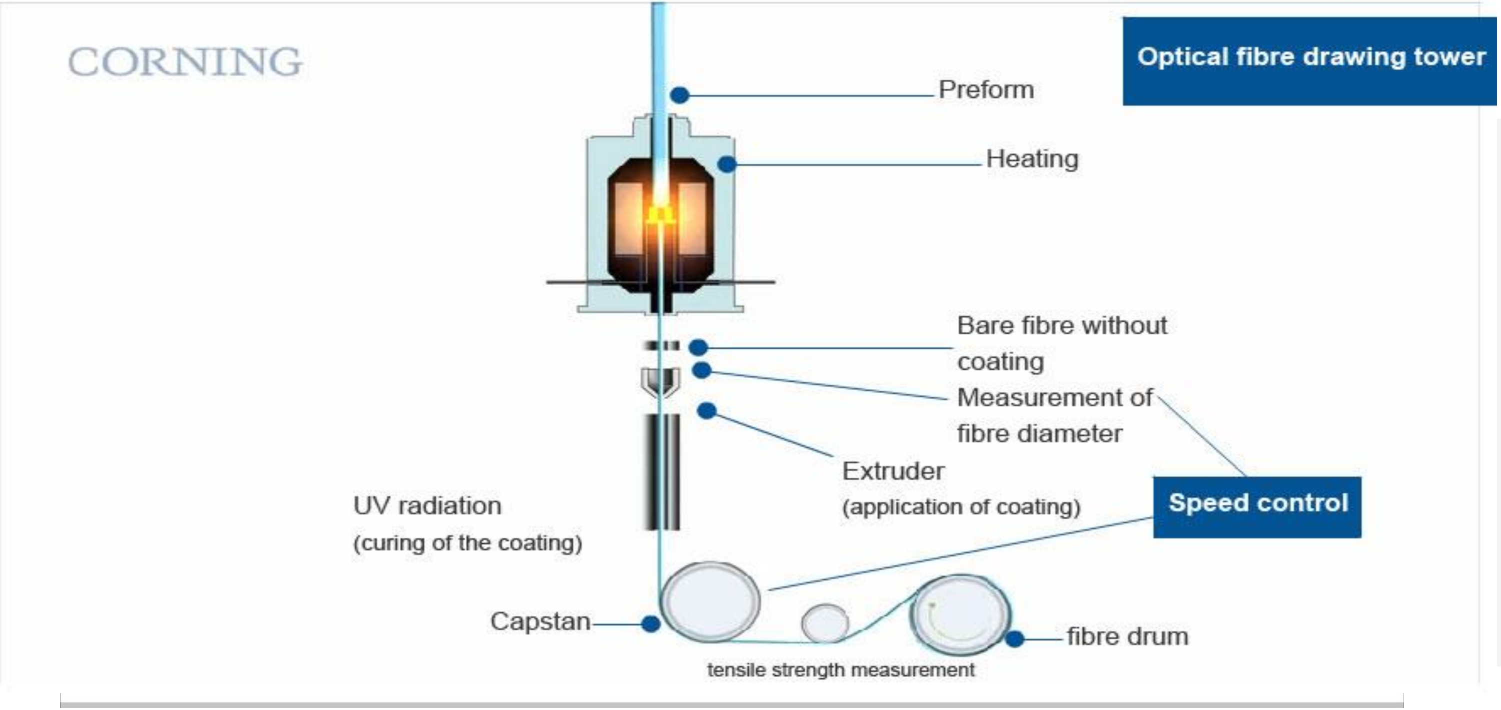
Distance Capabilities for Corning's EDGE8™, EDGE™ and Plug & Play™ Pre-Terminated Connectivity Solutions

AEN162, Revision 1

Table 1.2: Ethernet Duplex - Maximum Distance Capability for Systems with Multimode / Single mode Ultra Low Loss MTP/LC Modules (0.35/0.6) dB

Ethernet - Duplex - Maximum Distance Capability (All Distances in Meters)										
Fiber Type	Data Rate Protocol	Speed	Number of (MM/SM) Ultra Low Loss MTP/LC Modules (0.35/0.6) dB in the System							
			1	2	3	4	5	6	7	8
OM3-ULL	1000Base-SX	1 GbE	1155	1135	1115	1095	1070	1045	1020	1000
	10GBase-SR	10 GbE	325	325	325	325	325	325	325	325
	40GBase-BiDi	40GbE	110	110	110	110	110	110	105	105
OM4-ULL	1000Base-SX	1 GbE	1190	1170	1150	1130	1110	1085	1060	1030
	10GBase-SR	10 GbE	565	560	555	550	540	535	525	520
	40GBase-BiDi	40GbE	200	200	200	200	195	185	180	175
OS2-ULL	100G CWDM4	100G	2000	2000	2000	2000	2000	2000	2000	2000

The Making of Optical Fibre



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