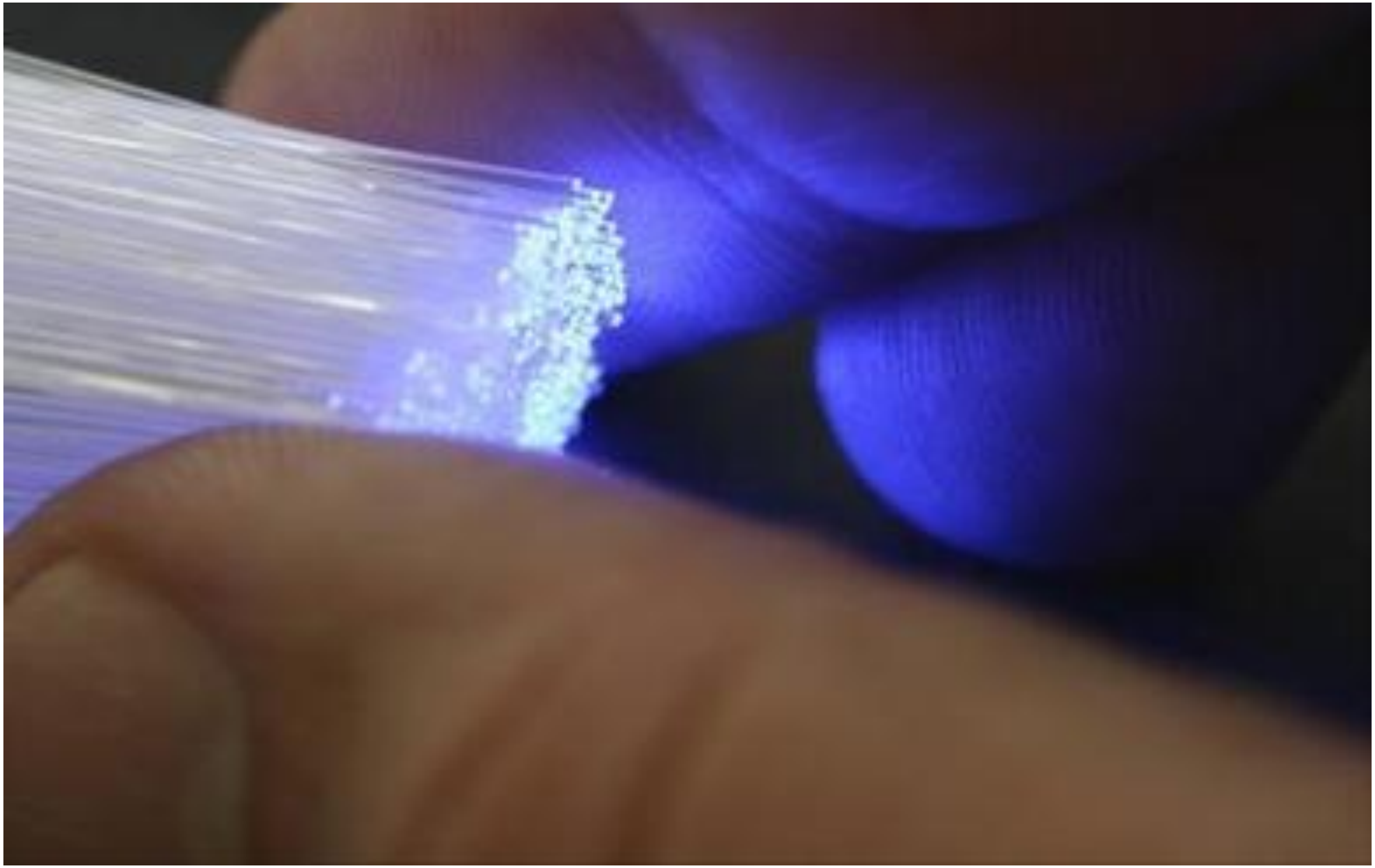
Fiber Technology



Optical fiber introduction

History of telecommunication engineering:

End of the 18th century: First telephone connection
End of the 19th century: First radio communication
Beginning of the 20th century: Radio transmission with modulation

Already in 1940 the first optical fiber was manufactured. But not before1966 it has been suggested, to use optical fiber for data transmission. However, former optical fibers had an attenuation of 1000 dB/km. So the range was very short and not useful for any application at this time.

1970 the company *“Corning”* was able to produce an optical fiber with an attenuation of less than 20 dB/km.
1979 the company “Sumitomo” made the break trough by developing an optical fiber with an attenuation of 0,2dB/km

This attenuation is still valid until today.

Comparison of copper and optical fibers

Key benefits of fiber optical systems compared with electrical systems are the low attenuation and high bandwidth.
The bandwidth is the frequency range that can be used for the data transmission.
Furthermore there is also the Bandwidth-Length Product (BLP).
It specifies the maximum length according to the data rate, and gives a number of how much information can be transmitted over the fiber.
The value is specified in “**MHz x km”** or “**Mbit/s x km”**.
When using a very high bandwidth normally the Bandwidth-Length Product limits the length, and not the attenuation of the optical fiber.

Key benefits of the optical transmission compared to the conventional way of wiring with copper conductors:

Mechanical advantages:
- Optical fibers are thin, lightweight and flexible
- Optical fibers are tensile (up to 50-60N, tactical cable up to 100N) and are very easily installed.

Transmission method advantages:
Very high transmission bandwidth with a high number of signals (Multiplexing: different signals are multiplexed)

Outstanding properties of optical fibers for data transmission:

Small signal attenuation on long transmission paths.

Interference resistance - no influence by electromagnetic noise fields.

No crosstalk between different fibers.

The transmission medium is a dielectric medium, thereby potential separation and no ground loops.

Very high safety from interception: when a fiber is tapped it is easily possible to measure the loss of light. The received signal level drops.

Protection against lightning, optical fibers are isolators.

Ex-Protection, no spark formation by disconnecting or broken fiber. No risk of explosions in sensitive explosive environments.

Very low aging, chemical and thermal stability.

Commercial advantages:

- Unlimited material availability (quartz sand)
- Reduction of costs for shielding and other fault clearance provisions, necessary for copper cables
- Very good cost/performance ratio, especially for very long transmission paths

Disadvantages:

- Higher assembly costs e.g. connectors, active components
- Higher costs compared with copper lines for short distances

Application - and operational areas:

Resulting from the previously shown pros and cons there are different application areas for fiber optical technology:

Long distance connections with a very high data throughput like telecommunication, cable TV, undersea cable, trunk cables.

Cross linking of buildings and factory premises:
The norm DIN EN 50173 says network cabling in primary environments (building to building and also in the secondary environments (floor to floor) need to be optical fiber infrastructures.

Connections in Ex-endangered areas (chemical industry, mining industry)

Metro networks e.g. FTTx:	Fiber to the Home Fiber to the Desk Fiber to the Curb Fiber to the Building
Event area:	Formula 1, MediorNet

Physical basics

Light (infrared light) is used for the data transfer.
Most people don’t see light as an electromagnetic wave. But just like radio waves (Television, Radio) light is an electromagnetic wave from a physical point of view.
The only difference between radio waves and light is the frequency.

The alternating current coming from our power sockets is also an electromagnetic wave with a frequency of 50Hz.
„**Hz**“ (Hertz) stands for oscillations per second.
The low frequency range is from 0Hz to 100kHz. For example the frequency range of the human voice.

The high frequency range (HF) is from 100kHz to 850MHz. Used for example for terrestrial TV, Radio, LW, MW ,KW, VHF.

All higher frequencies, up to 6GHz are the Microwaves. Used for example for Radar, radio link systems.

X-rays, Gamma- und cosmic radiation, located above 6000 THz are also are electromagnetic waves.
Light is using a frequency of about 380 - 750THz. Because these are very big numbers which are difficult to handle, “Wavelength” is used as the measurement for the light.

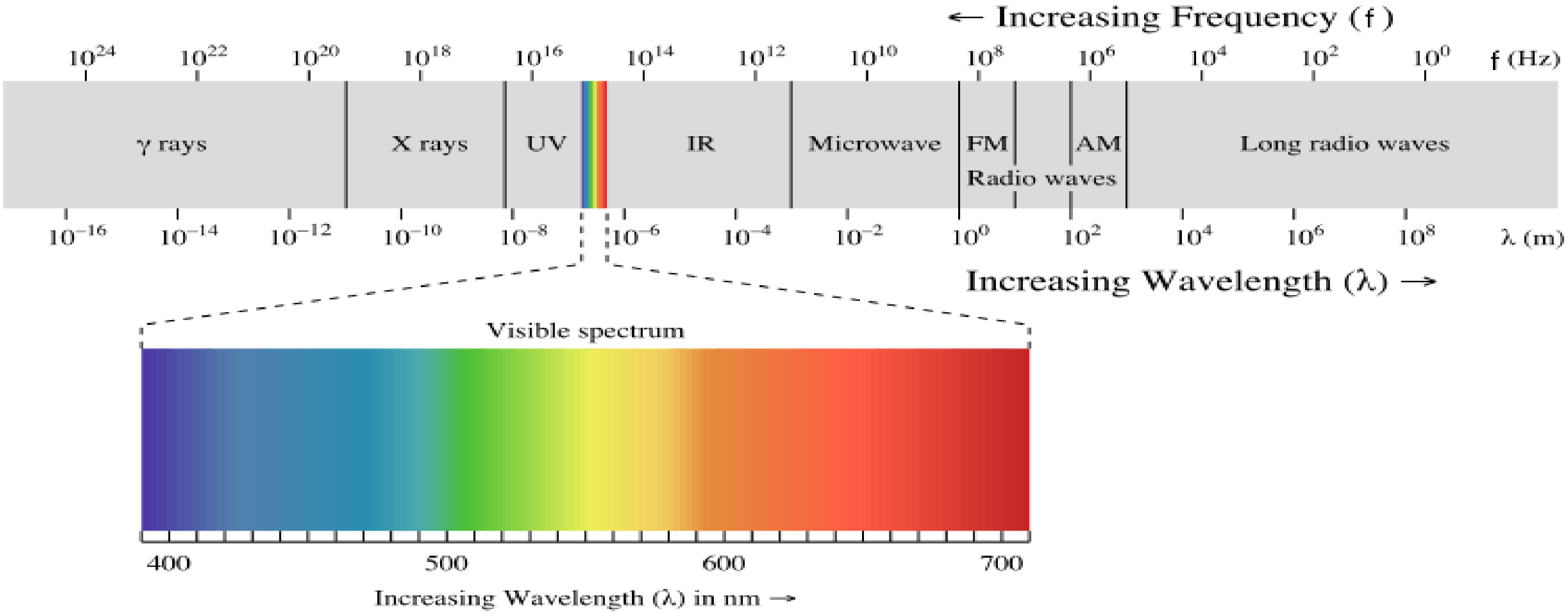
$$\lambda = \frac{v}{f}$$

λ (Lambda) is the wavelength
v is the velocity of the wave (default is velocity of light in vacuum: 300.000 Km/s)
f is the frequency

The higher the frequency, the lower is the wavelength.

Visible light has a wavelength of about 380 -750nm. The color “red” is around 635 - 650 nm.
For the typical data transmission inside an optical fiber wavelengths of 850 nm, 1300/1310 nm, 1550nm and 1625 nm are used (all are in the infrared spectrum).

For special applications like WDM (**W**avelength **D**ivision **M**ultiplexing) or DWDM (**D**ensed **W**ave **D**ivision **M**ultiplexing) multiple wavelengths can be used simultaneously inside a single optical fiber.



Refraction number or refraction index:

Refraction: The speed of the wave changes due to change of medium of travelling, this is known as refraction.

The propagation speed of light is around 300.000 km/s inside vacuum.

Inside water the propagation speed is around 225.000km/s, inside glass around 200.000km/s.

The decrease of the speed is caused by the refraction number of the different materials.

Vacuum has got a refraction number of exact 1, water around 1,33 , glass around 1,5.

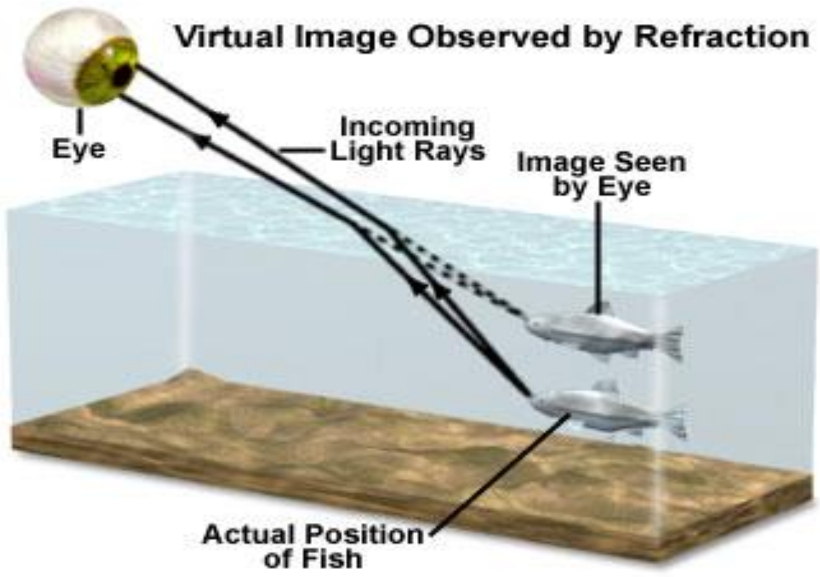
Formula for the calculation of the propagation speed of light:

$$c = \frac{c_0}{n} \qquad \text{Speed of light [m/s]} = \frac{\text{Speed of light in vacuum [m/s]}}{\text{Refraction number}}$$

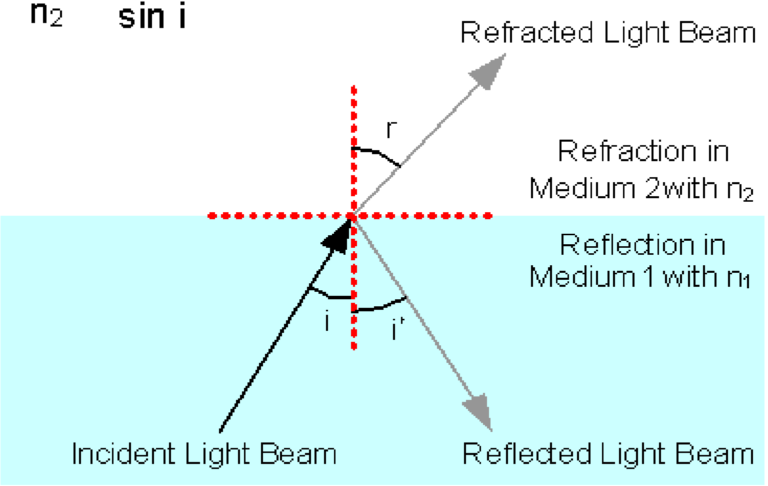
The refraction index is the deciding factor allowing light to be sent trough an optical fiber, even when the optical fiber is not run absolutely straight (as is usually the case).

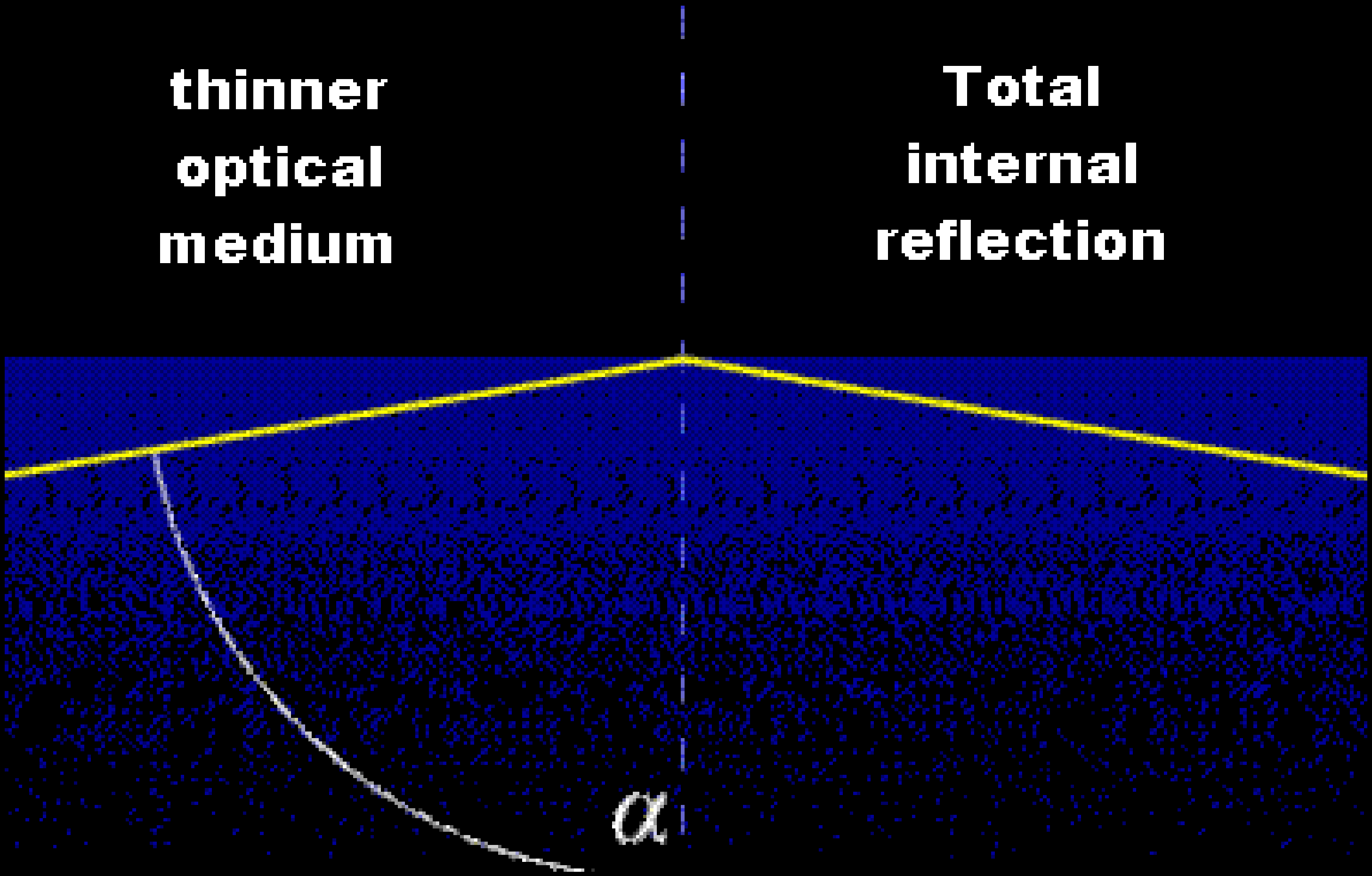
The refraction index plays an important role, especially when light crosses two materials with different optical densities.

You know this effect also from your daily routine. Think about a lake with a swimming fish inside.
When you are standing on the water´s edge you can see the fish. Now try to catch it (like you see the fish). You will miss the target.
This effect was realized 1792 by Snellius. He converted it into a formula:



$$\frac{n_1}{n_2} = \frac{\sin r}{\sin i}$$

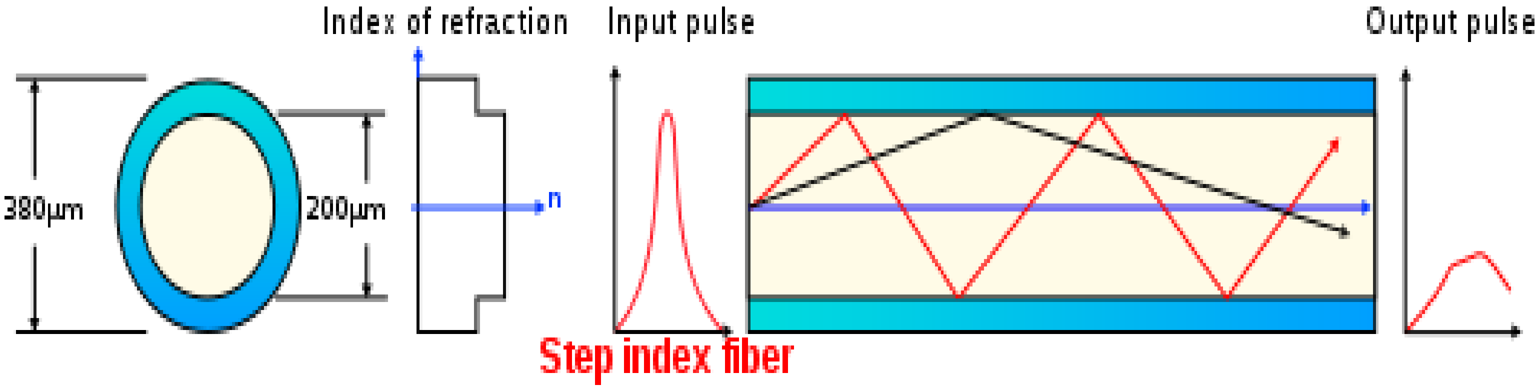




thinner
optical
medium

Total
internal
reflection

Multimode fiber with step index:



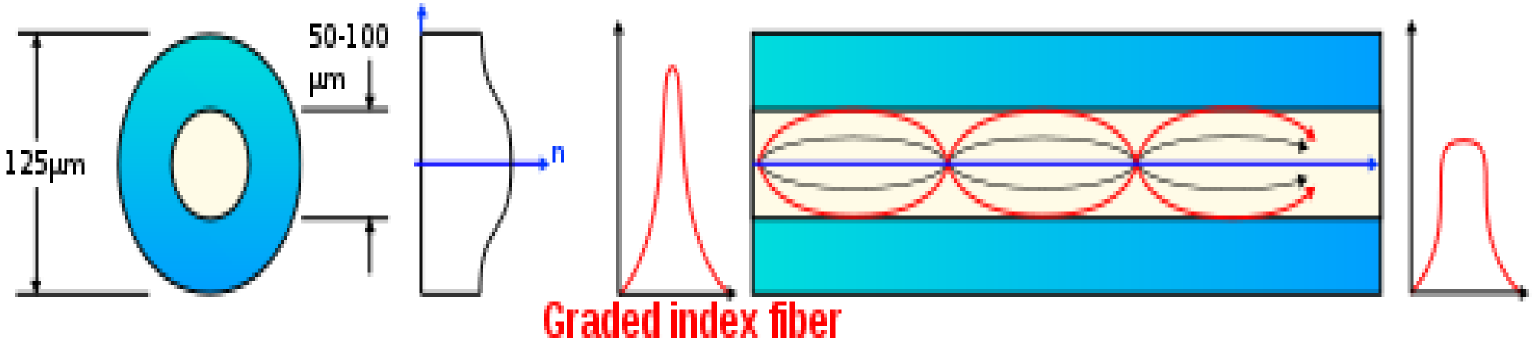
Typical core diameters: 100µm, 200µm, 300µm **Typical sleve diameters: 200µm, 300µm, 500µm**

As you can see in the drawing, many modes („light beams“) can be transmitted simultaneous. Depending of the input angel it needs more or less time for the same fiber length than other „light beams“. The result is a widening of the output signal.

This effect is also called “modal dispersion” or “multimode distortion” and limits the maximum bandwidth up to a specific fiber length. The Bandwidth-Length-Product (can be found in the datasheet of the cable) describes this limit value, caused by the modal dispersion.

Actually multimode fibers with step index can only be found in the industry.

Multimode fiber with graded index:

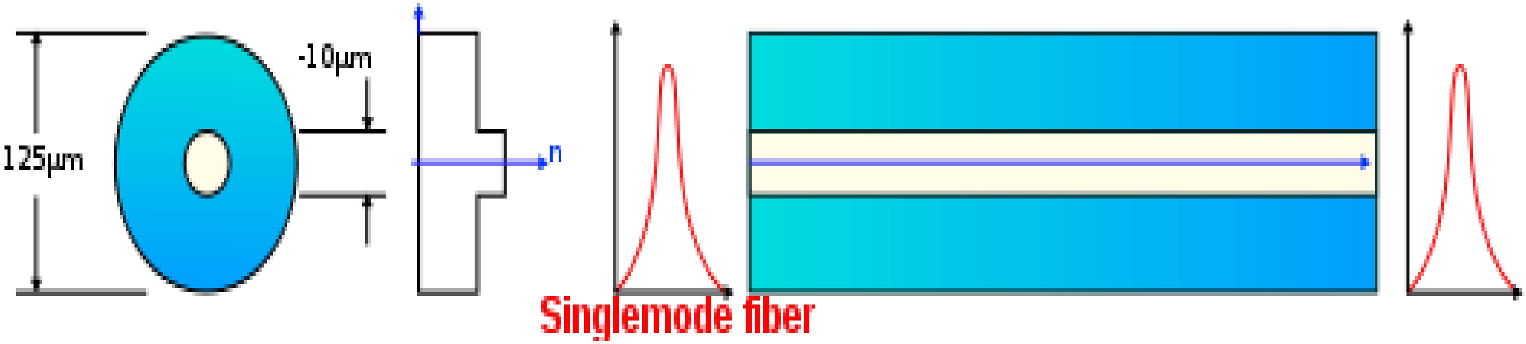


Typical core diameters: 50µm, 62.5µm **Typical sieve diameter: 125µm**

This is the „standard“ fiber optic cable like it is used for example in company networks. As you can see on the output signal, the dispersion effect is still present but significantly less than in fibers with the step index.

The refraction index is changing continuously inside the layers You can imagine the layers like the layers of an onion.

Single-mode fiber:



Typical core diameter: 9µm **Typical sleve diameter: 125µm**

This optical fiber is used particularly in wide area networks.

But the monomode fiber is increasingly used also for other networks where very high data rates are needed.

Structure:

Up to now, only the structure of the pure fiber was described. But glass by itself is very sensitive and can break very easily. Therefore additional protection layers are used.

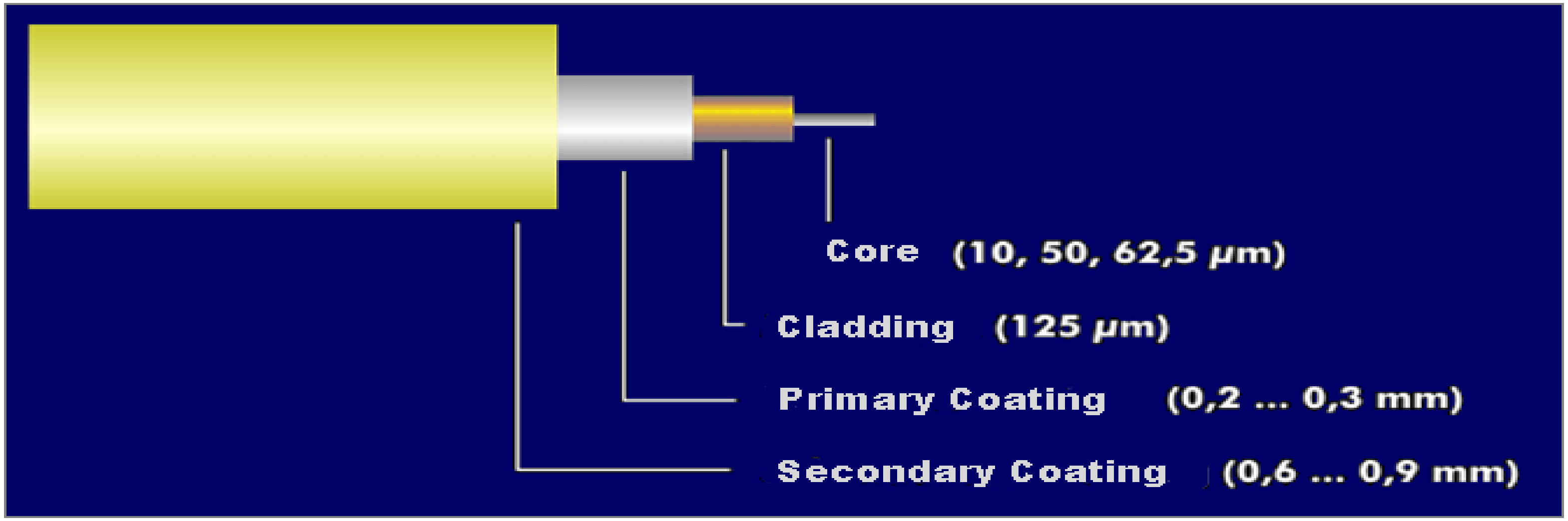
Basically there is a special coating covering the fiber. The coating is a very thin plastic material.

With this plastic material the fiber obtains a certain tensile strength and can be bent without breaking. Nevertheless a minimum bending radius needs to be observed.

Sometimes you can find the specification printed on the cable, like 50/125/250.

This means, it is a fiber with a core diameter of 50 µm, a fiber cladding of 125 µm and a coating diameter of 250 µm.

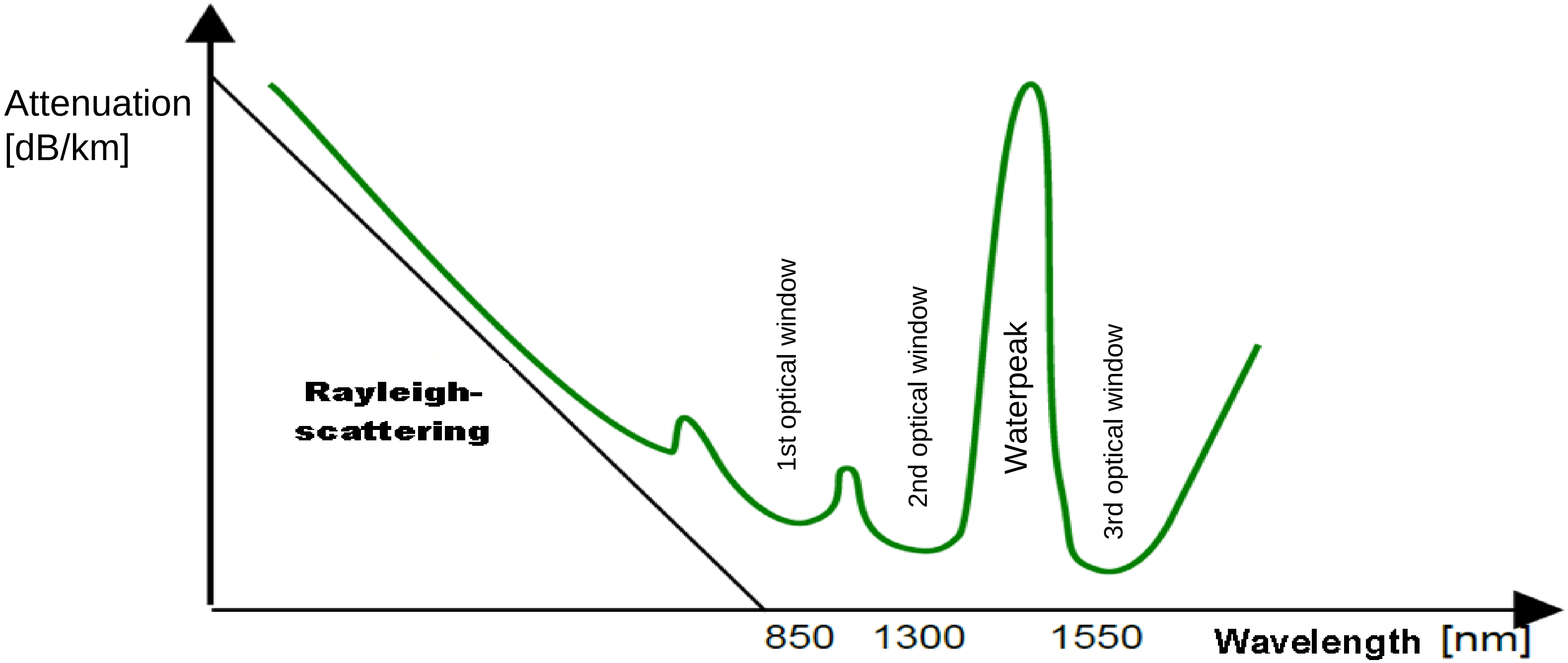
On fiber optical patch cables there is also an additional cover around the fiber, that is not bonded directly with the fiber.



Attenuation:

The attenuation is the most important parameter for long fiber optic cables.
The attenuation of a fiber optic cable depends on the wavelength used.

The attenuation characteristics relatively to the wavelength used looks as follows:



For the data transmission in a network only the „windows“ with the lowest attenuation are used. These windows can be found at the wavelengths 850 nm, 1300 nm and 1550 nm.

These attenuation characteristics are only valid for quartz-glass fibers.
For POF (**P**lastic **O**ptical **F**iber) the attenuation characteristics are different. The optimal range here is around 635 to 650 nm.

In general it is also possible to transmit a wavelength of 850nm via a singlemode fiber.
But in the common practice multimode fibers have a wavelength of 850nm and 1300nm, and single mode fibers use 1310nm and 1550nm for data transmission.
The declaration 1300 and 1310 is just for a better differentiation.

Now the question is, why not use only 1550nm which has the lowest attenuation for data transmissions?

The reason is historical and is based on the different components that were user for different wavelengths.
Initially the more easy to handle technical components were developed, which work with 850nm.

LEDs (**L**ight **E**mitting **D**iode) are used for multi-mode and LASERs (**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation) are used for single mode inside the transmitter modules of the devices. LASERs are much more complex to build, and therefore more expensive. That’s the reason for the significant price differences of devices using multi mode or single mode fibers.

In the meantime, also the range of 1300nm to 1550nm is useable because of a special manufacturing process. It is called the “Allwave”- or “No-Water-Peak” fiber

Because of this process, a larger range of wavelength can be used for example for DWDM (**D**ensed **W**ave Length **D**ivision **M**ultiplexing) to have more channels (=wavelength) available for the simultaneous data transmission.

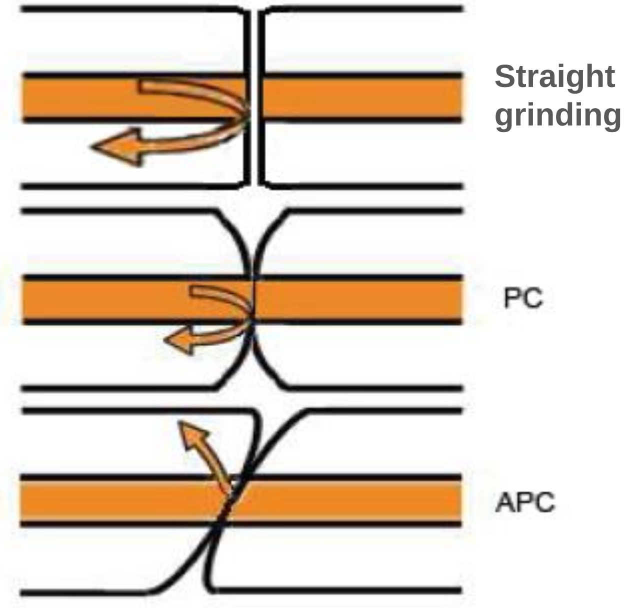
The attenuation of an optical fiber link consists of:

- Insertion Loss (IL) > Losses on connector / connector - transitions
- Attenuation of the fiber > Losses on the fiber path
- Splice attenuation > Losses caused by connecting fibers

Another rating for the quality of a plug connection is important:

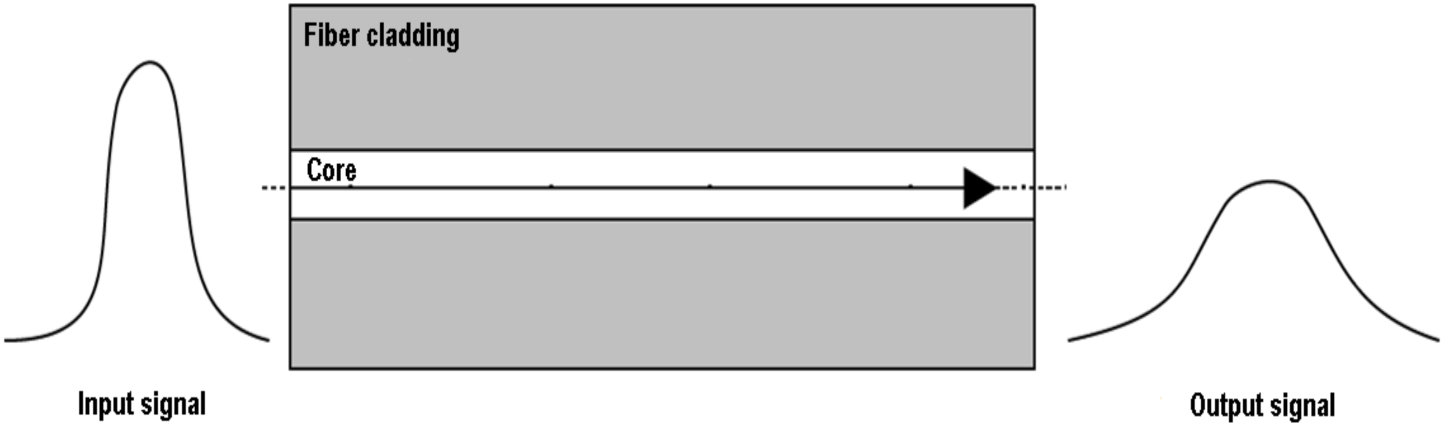
The Return Loss attenuation (RL)

A portion of the light will be reflected on the fibers end / plug connections.



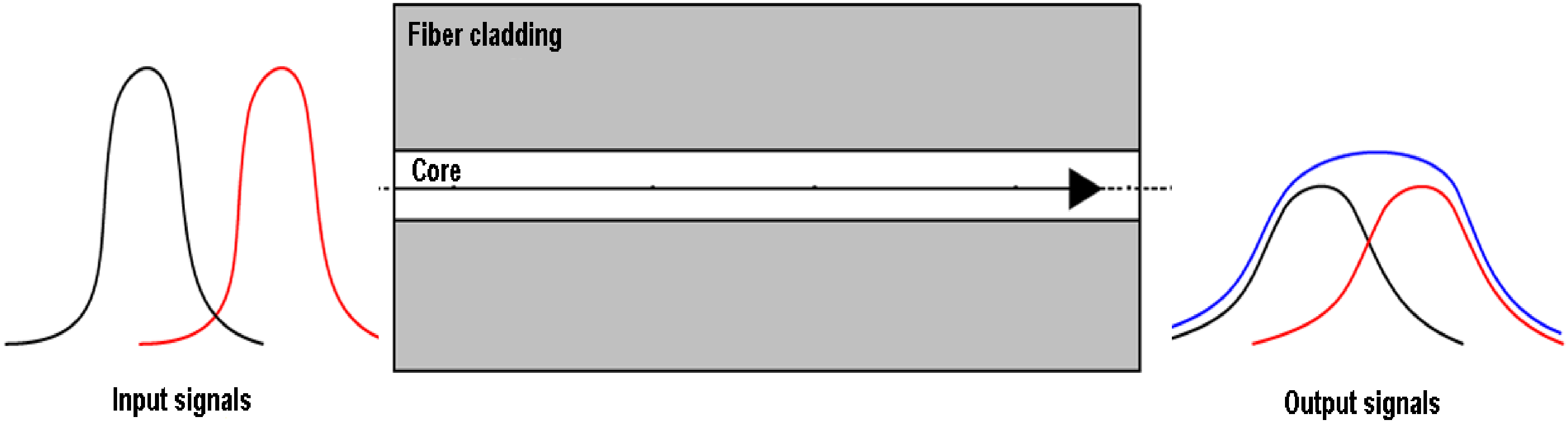
Dispersion

The dispersion is the spreading of a signal inside an optical fiber caused by different delays.
The signal is broadened so that the impulse requires more time. The longer the distance of the fiber, the broader is the output signal.
Simultaneously the amplitude of the signal is lowered, because the inserted energy of the light is scattering for a longer period of time.



For single impulses this effect is not relevant, because the receiver only needs to detect a single impulse.
But if the speed of transmission is increased, thus also the number of light impulses per time (typically per second), overlaps can be the result.

On the overlaps, the light energy is summed. From a certain speed up (data rate) the light impulses are blurred.
The receiver can no longer differ between the two light signals and the result is interpreted as one long single impulse. The results are transmission errors or in the worst case a complete breakdown of the transmission.



There are different types of dispersions.

They are, in order of their importance:

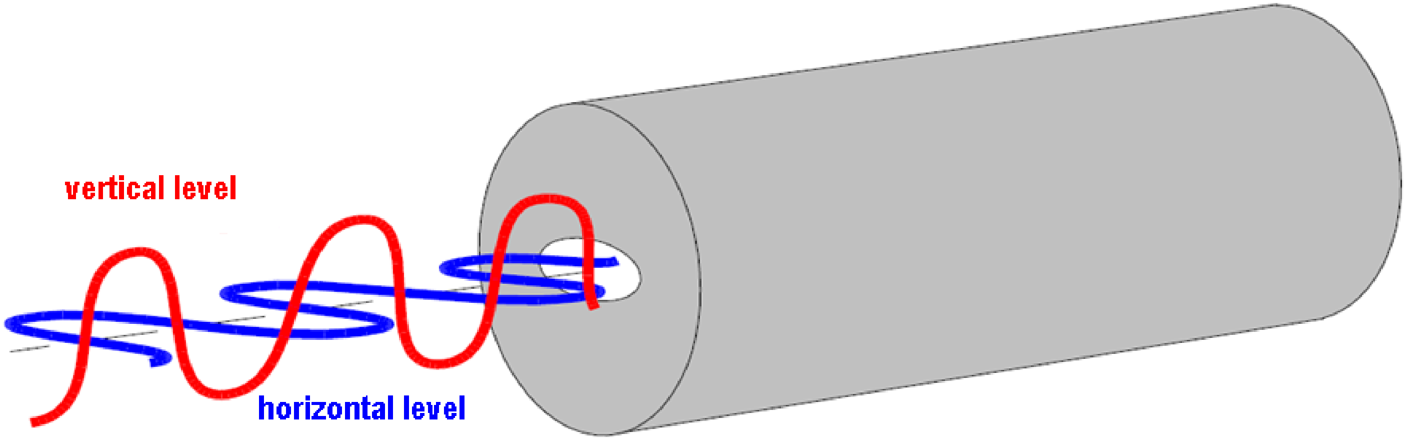
Mode Dispersion – This only happens in multi mode fiber, when multiple light beams are used for the data transmission. The influence on the signal is so big, that all other types of dispersions can be disregarded.

Chromatic Dispersion (CD) – As the name already suggests (chroma: greek = color), it is the difference of run duration for the different colors. With “color” meaning different wavelengths.
Different colors have different run durations through an optical fiber.
A LASER for single mode is not only transmitting a light beam with 1550nm, also it has got a wider spectrum. This means: A part of this light is sent e.g. with 1549,9nm and another part with 1550,1nm. Different colors are the result.

The Chromatic Dispersion is the most dominant type of dispersion for data transmissions within single mode optical fibers.

Polarisations moden Dispersion (PMD) – is a form of modal dispersion where two different polarizations of light in a waveguide, which normally travel at the same speed, travel at different speeds due to random imperfections and asymmetries.
Light is an electromagnetic wave, and an electromagnetic wave is oscillating and spreading horizontally and vertically.
In an ideal optical fiber, the core has a perfectly circular cross-section. In an realistic fiber the diameter and also the lateral cut. Mostly the lateral cut is slightly elliptically.

The result is that the light in horizontally direction is more decelerated than in vertically direction causing random spreading of optical pulses. Unless it is compensated, which is difficult, this ultimately limits the rate at which data can be transmitted over a fiber.



All types of dispersion are material properties.
Normally they can be found in the datasheets of the fiber optic cables.
Theoretically the result of the polarization modes can be slightly influenced by how the cables are installed.
Practically the influence of the installation way can be completely disregarded.

Definitely the dispersion effects are unwanted, especially in wide are networks.

But there is a special fibers available that invert the dispersion effect.
Therefore after a length of about 80km a piece of 1km is spiced into the cable. It is called *Dispersion Shifted Fiber* (DSF) or *Nonzero Dispersion Shifted Fiber* (NZDSF) .

These special fibers are extremely expensive and also they have a higher attenuation than standard fibers.

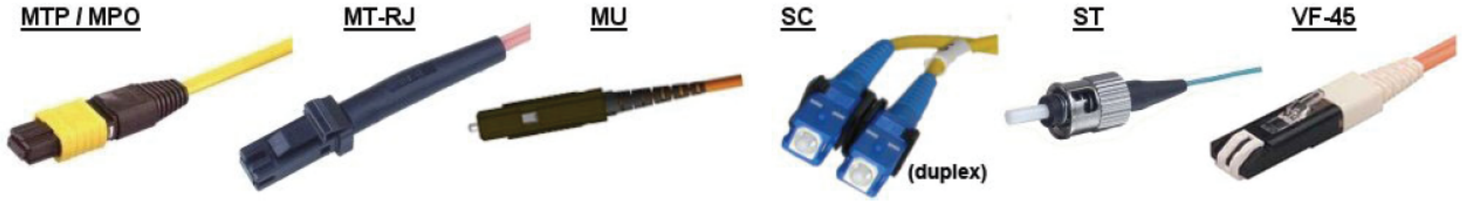
Additionally on wide area networks amplifiers are necessary every 60 km. These amplifiers amplifier the signal or also rebuild it completely.

Dipl.-Ing. (FH) Karl Loncarek
Key Account Manager
Black Box Network Services

Overview fiber connector types

KSI Kontakt Systeme Inter Ges.m.b.H.	**DIN / LSA**	**E-2000™**	**F-3000™**	**FC**	**FDDI / MIC**	**F-SMA**	**LC**
Standards /	DIN 47256 IEC 874-6	IEC 61754-15 TIA/EIA 604-16	IEC 61754-20 TIA/EIA 604-10-A	IEC 61754-20 CECC 86115-801	ISO 9314-3 ANSI X3.166	IEC-SC 86B(CO)20 CECC 86104	IEC 61754-20 TIA 604-10-A
Verwendung	TEL LAN WAN	LAN WAN CATV	TEL LAN CATV	TEL	FDDI ATM	alle	alle
Verbreitung	nur DE AT CH	zunehmend	zunehmend	abnehmend	häufig	selten	häufig
SM / MM	● / ●	● / ●	● / ●	● / ●	● / ●	○ / ●	● / ●
ReturnLoss							
SM / APC	45dB / 55dB	50dB / 70dB	50dB / 70dB	50dB / 70dB	30dB / -	- / -	50dB / 70dB
MM	20dB	40dB	40dB	40dB	-	30dB	40dB
InsertionLoss							
SM / APC	0,2dB / -	0,2dB / 0,2dB	0,2dB / 0,2dB	0,1dB / 0,1dB	0,2dB / -	- / -	0,12dB / 0,12dB
MM	0,2dB	0,15dB	0,15dB	0,15dB	-	1.0dB	0,2dB
Ferrule Ø	2,5mm	2,5mm	1,25mm	2,5mm	2,5mm	3,175 / 2,5mm	1,2,5mm
Material	Metall / Zirkonia	Zirkonia/Neusilber	Zirkonia/Neusilber	Metall / Zirkonia	Zirkonia	Metall	Zirkonia
Tuning	○	vorzentriert	vorzentriert	●	○	○	●
Schutzklappe	○	●	●	○	○	○	○
Verriegelung	schraub	Raste / Hebel	Raste / Hebel	schraub	Snap-In	schraub	Snap-In
Duplexierbarkeit	○	●	●	○	○	○	●
Multifiber	○	○	○	○	2	○	●
Small**F**orm**F**actor	○	○	●	○	○	○	●
Kodierung	○	●	●	○	●	○	●
Steckzyklen	2000	1000	1000	2000	1500	2000	1000
Besonderheiten		auch in max. 0,1dB verfügbar	auch in max. 0,1dB verfügbar / LC kompatibel			einer der ersten standardisierten LWL-Stecker	auch mit 0,06dB (SM) verfügbar

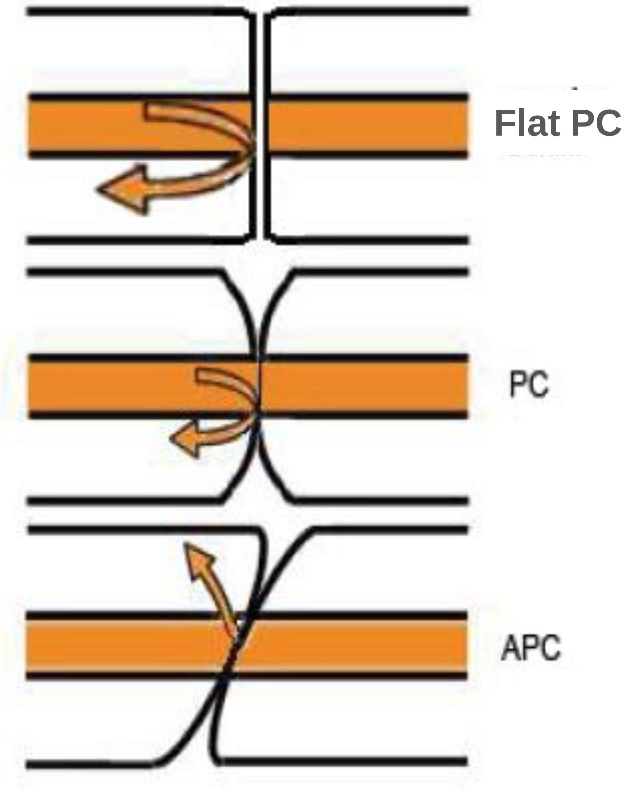
KSI Kontakt Systeme Inter Ges.m.b.H.	**MTP® / MPO** 	**MT-RJ** 	**MU** 	**SC** 	**ST / BFOC** 	**VF-45** 
Standards / Normen	IEC 61754-7	IEC 61754-18 TIA/EIA 604-12	IEC 61754-6 TIA/EIA 604-17	IEC 61754-4 TIA/EIA 604-3A	IEC 61754-2 TIA/EIA 604–2	IEC 61754-19
Verwendung	SAN LAN	LAN	TEL LAN CATV	alle	alle	LAN
Verbreitung	selten	häufig	selten	sehr häufig	sehr häufig	häufig
SM / MM	● / ●	● / ●	● / ●	● / ●	● / ●	○ / ●
ReturnLoss						
SM / APC	- / 55dB	35dB / -	50dB / 70dB	50dB / 70dB	40dB / 45dB	- / -
MM	20dB	20 dB	40dB	40dB	20dB	30dB
InsertionLoss						
SM / APC	- / 0,25dB	0,3dB / -	0,12dB / 0,12dB	0,12dB / 0,12dB	0,2dB / -	- / -
MM	0,2dB	0,2dB	0,15dB	0,2dB	0,2dB	0,35dB
Ferrule Ø	2,5 x 6,5mm	2,5 x 4,5mm	1,25mm	2,5mm	2,5mm	-
Material	Keramik / Kunststoff	Kunststoff	Keramik	Keramik	Keramik / Metall	
Tuning	○	○	●	●	○	○
Schutzklappe	○	○	○	○	○	●
Verriegelung	Push / Pull	Push / Pull	Push / Pull	Push / Pull	Bajonett	Push / Pull
Duplexierbarkeit	○	○	●	●	○	○
Multifiber	max. 24	max. 8	○	○	○	2
Small**F**orm**F**actor	○	●	●	○	○	●
Kodierung	○	○	●	●	○	○
Steckzyklen	1000	500	500	1000	1000	500
Besonderheiten			aufgrund seiner Ähnlichkeit auch Mini-SC genannt	auch mit 0,06dB (SM) verfügbar	nicht mehr empfohlen!	

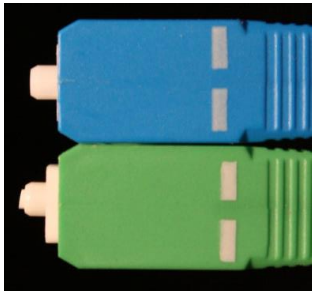


Flat PC:
The ferrules physically contact each other instead of a air gap in between.
Reflection: -30dB

PC (Physical Contact)
Typical Back Reflection: <-40dB

APC (Angled Physical Contact)
Ferrule end has a 8° angle which minimizes back reflection
Typical Back Reflection: <-60dB



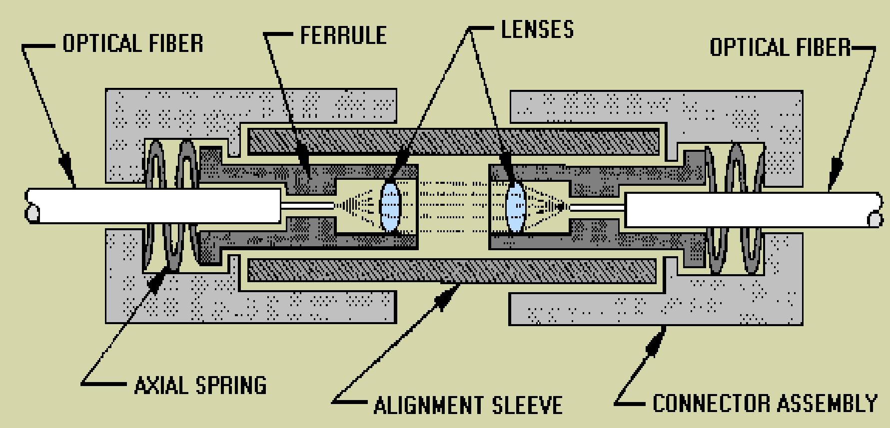


PC - SC connector

APC - SC connector

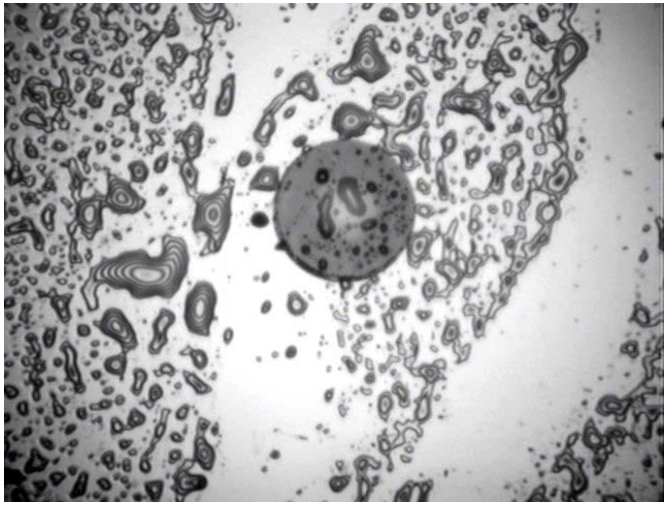
Grey (normally)	Multimode-connector
Blue	Singlemode-connector PC
Green	Singlemode-connector APC

Expanded beam connector

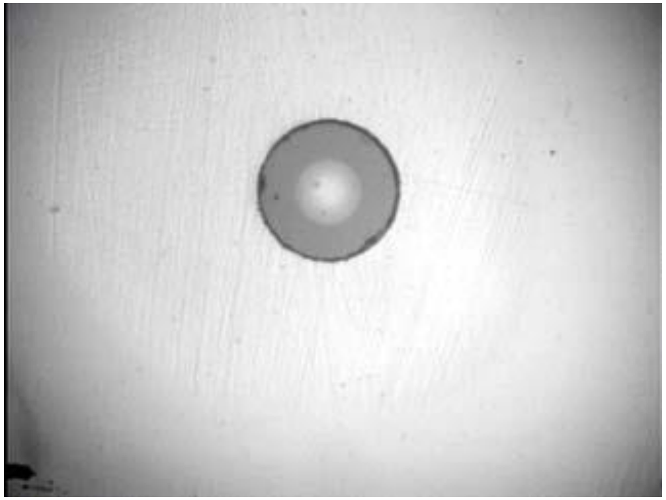


Always clean connectors before plugging

Always protect connectors and couplers with the dust covers



Before cleaning…

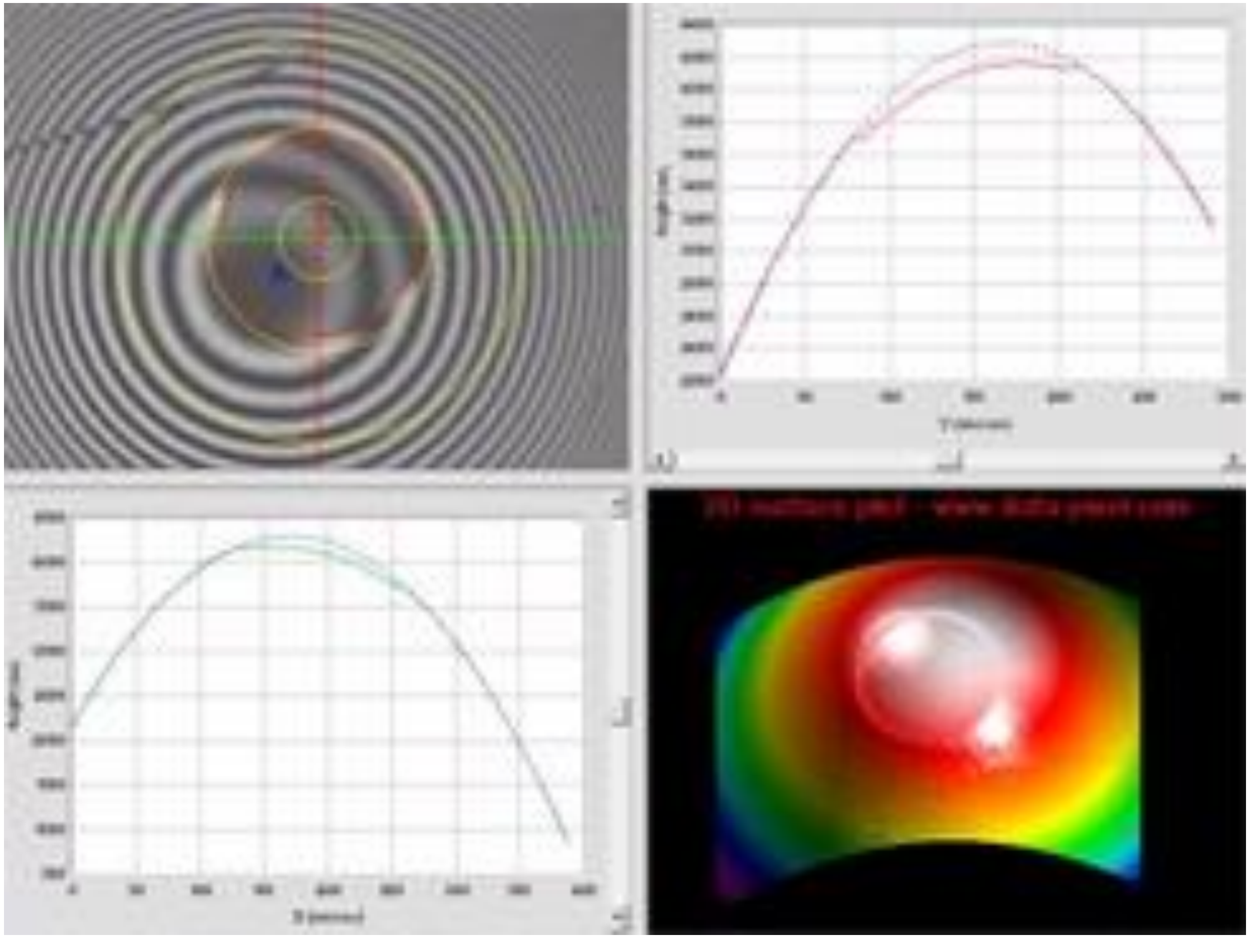


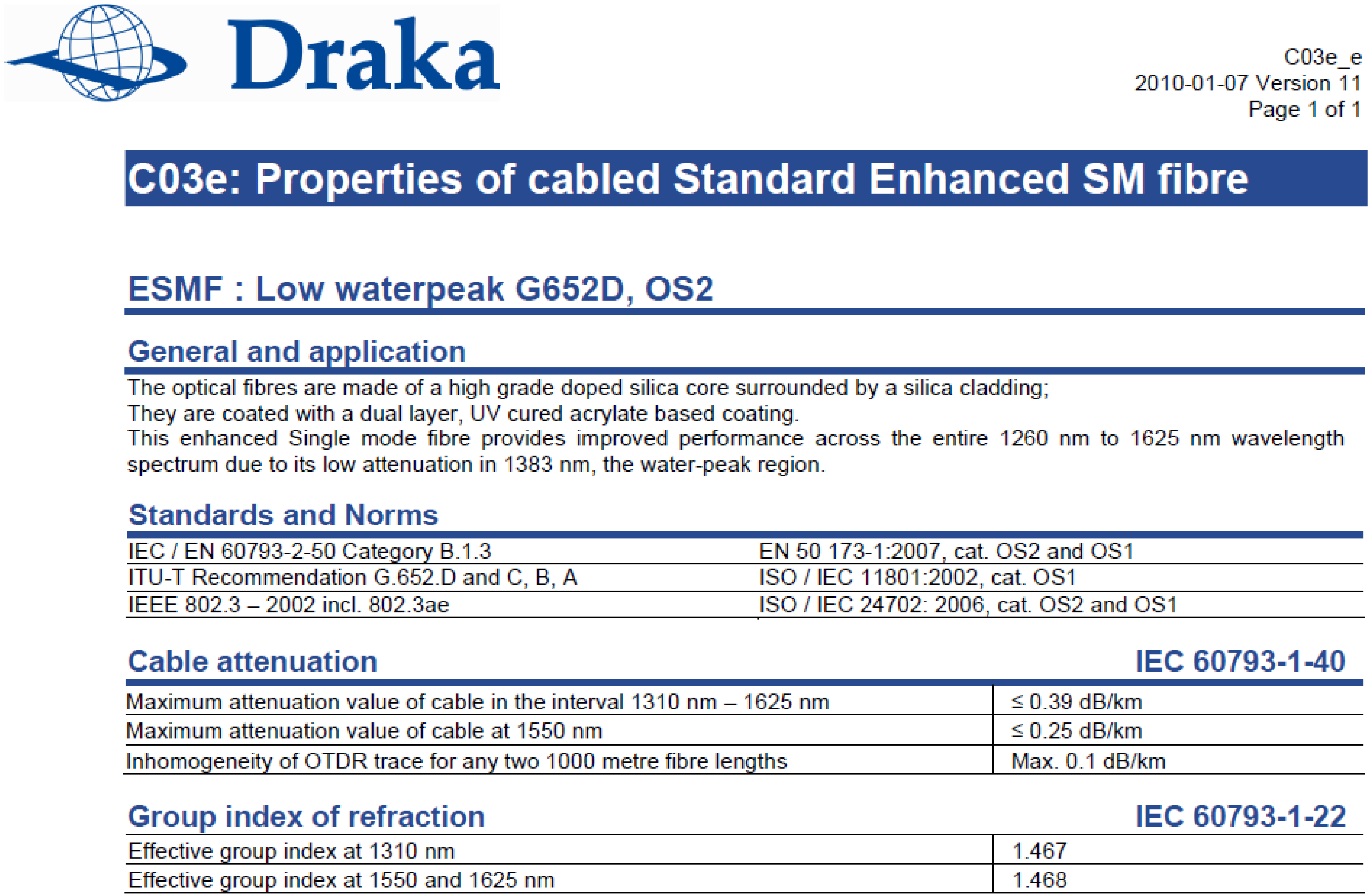
…after cleaning

Fiber Optic Bandwidth per Cable Size

Ethernet Data Rate (Gbps)	Fiber Size (µm)	Bandwidth @ λ: 850/1300 nm (MHz)	Bandwidth @ λ: 1310/1550 nm (THz)	Average Distance (km)
0.1	62.5/125	200/500	-	2
0.1	50/125	500/500	-	2
0.1	9/125	≈ 100	100	
1	62.5/125	200/500	-	0.22
1	50/125	500/500	-	0.55
1	9/125	-	≈ 100	70
10	62.5/125	200/500	-	0.035
10	50/125	500/500	-	0.065
10	50/125 VCSELs Optimized	2000/500	-	0.3
10	9/125	-	≈ 100	40

Interferometer





C03e_e
2010-01-07 Version 11
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C03e: Properties of cabled Standard Enhanced SM fibre

ESMF : Low waterpeak G652D, OS2

General and application

The optical fibres are made of a high grade doped silica core surrounded by a silica cladding;
They are coated with a dual layer, UV cured acrylate based coating.
This enhanced Single mode fibre provides improved performance across the entire 1260 nm to 1625 nm wavelength spectrum due to its low attenuation in 1383 nm, the water-peak region.

Standards and Norms

IEC / EN 60793-2-50 Category B.1.3	EN 50 173-1:2007, cat. OS2 and OS1
ITU-T Recommendation G.652.D and C, B, A	ISO / IEC 11801:2002, cat. OS1
IEEE 802.3 – 2002 incl. 802.3ae	ISO / IEC 24702: 2006, cat. OS2 and OS1

Cable attenuation IEC 60793-1-40

Maximum attenuation value of cable in the interval 1310 nm – 1625 nm	≤ 0.39 dB/km
Maximum attenuation value of cable at 1550 nm	≤ 0.25 dB/km
Inhomogeneity of OTDR trace for any two 1000 metre fibre lengths	Max. 0.1 dB/km

Group index of refraction IEC 60793-1-22

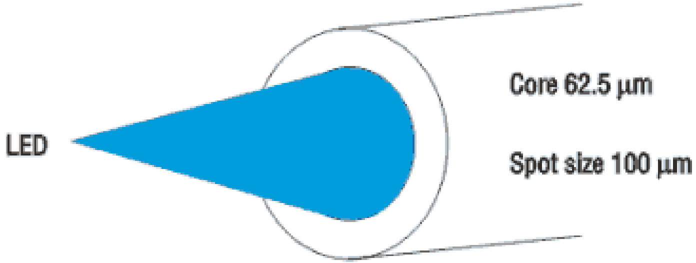
Effective group index at 1310 nm	1.467
Effective group index at 1550 and 1625 nm	1.468

Other properties

IEC 60793-1-xx

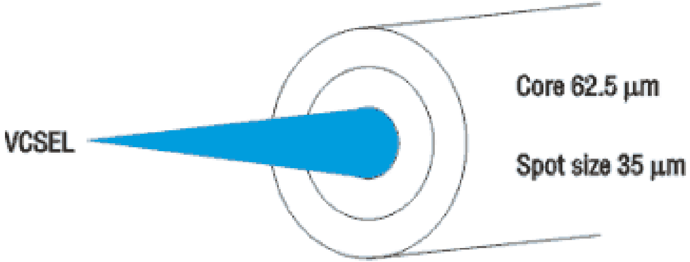
Cladding diameter	IEC / EN 60793-1-20	µm	125.0 ± 0.7
Cladding non-circularity	IEC / EN 60793-1-20	%	≤ 0.7
Core - cladding concentricity error	IEC / EN 60793-1-20	µm	≤ 0.5
Primary coating diameter – ColorLock™-XS coloured and natural	IEC / EN 60793-1-21	µm	242 ± 7
Primary coating non-circularity	IEC / EN 60793-1-21	%	≤ 5
Primary coating - cladding concentricity error	IEC / EN 60793-1-21	µm	≤ 12
Chromatic dispersion coefficient: In the interval 1285 nm – 1330 nm At 1550 nm At 1625 nm	IEC / EN 60793-1-42	ps/km • nm	 ≤ |3| ≤ 18.0 ≤ 22.0
Zero dispersion wavelength, λ_0		nm	1300 - 1322
Zero dispersion slope		ps/(nm^2 • km)	≤ 0.090
Cut-off wavelength	IEC / EN 60793-1-44	λ_{cc} nm	≤ 1260 *
Mode field diameter at 1310 nm Mode field diameter at 1550 nm	IEC / EN 60793-1-45	µm µm	9.0 ± 0.4 10.1 ± 0.5
Macrobending loss 100 turns on a ø 50 mm mandrel at 1310 and 1550 nm 100 turns on a ø 60 mm mandrel at 1625 nm	IEC / EN 60793-1-47	dB	 ≤ 0.05 ≤ 0.05
Polarisation mode dispersion (PMD) coefficient, max. uncabled	IEC / EN 60793-1-48	ps/√km	≤ 0.5
PMD_Q Link Design Value (calculated with Q=0.01%, N=20)	IEC / EN 60794-3	ps/√km	≤ 0.2
Proof stress level	IEC / EN 60793-1-30	Gpa	≥ 0.7 (≈ 1 % strain)
Fibre curl radius	IEC / EN 60793-1-34	m	> 4
Strip force (peak)	IEC / EN 60793-1-32	N	$1.2 \leq F_{\text{peak strip}} \leq 8.9$
Dynamic fatigue resistance aged and unaged (N_d)	IEC / EN 60793-1-33		≥ 20
Static fatigue resistance (N_s)	IEC / EN 60793-1-33		≥ 23

** guaranteed value according to the ITU-T (ATM G650) method*



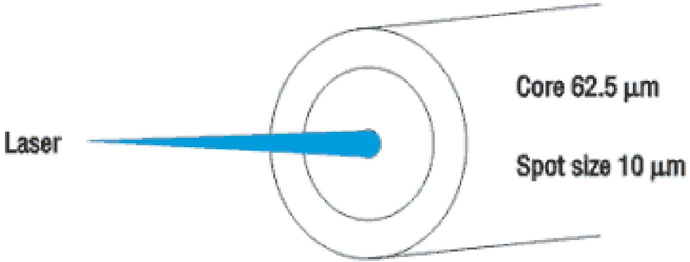
Light Emitting Diode

(A) FDDI Overfilled-Launch



Vertical Cavity Surface Emitting Laser (VCSEL)

(B) Gigabit Ethernet Short Wavelength



Single-Mode Laser

(C) Gigabit Ethernet Long Wavelength

What is WDM?

WDM basics explanation for our CWDM & DWDM systems:
In the information technology the transmission medium is called line.
A single line suffers to connect two devices, so that they can communicate which each other. For multiple devices also multiple lines are required.

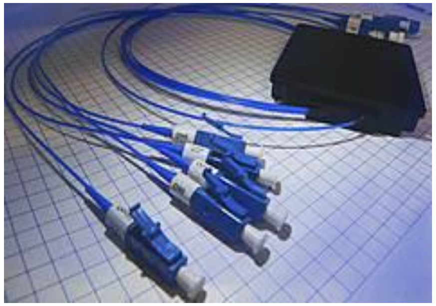
But if only a single line is available, it is not possible to connect multiple devices without further methods.
Therefore the WDM-technology can be used to use a single fiber optical line for multiple signals.

The idea behind the WDM technology:
A Laser is producing a light beam with a certain wavelength (colors)

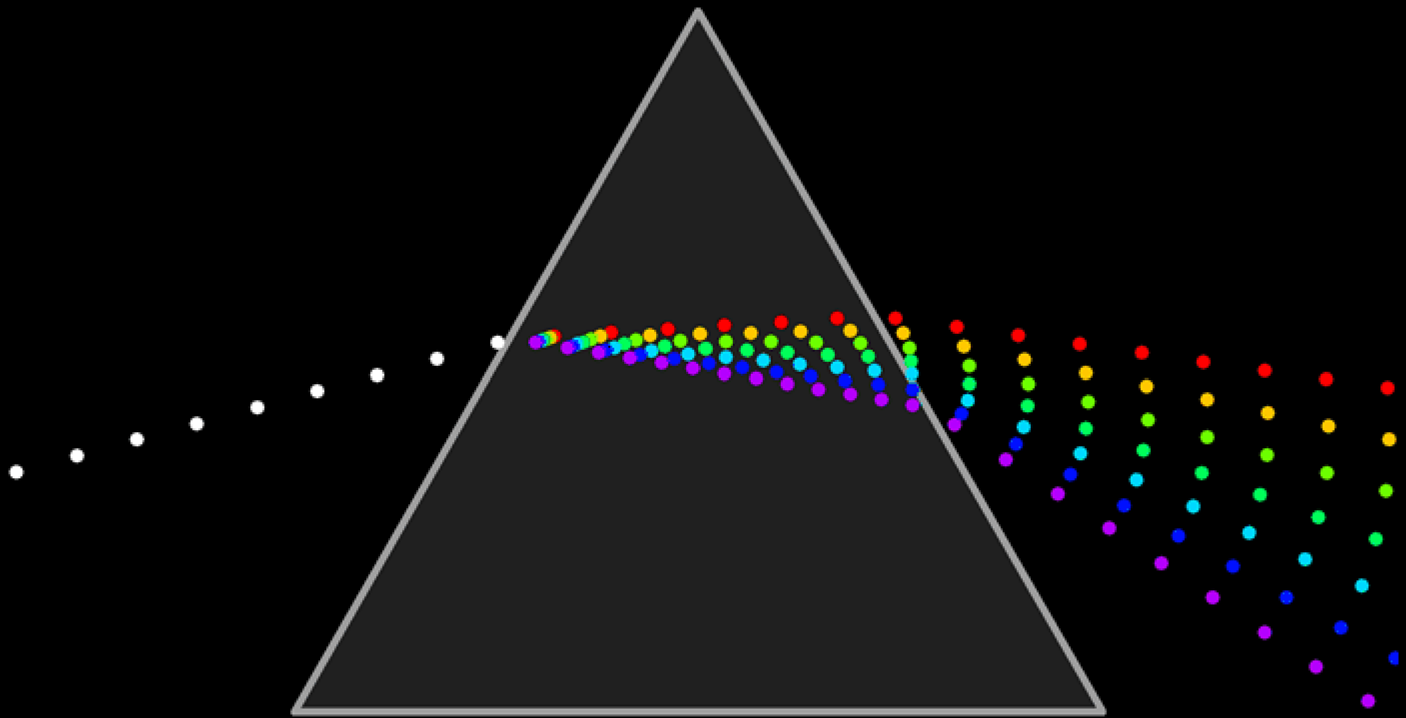
A WDM multiplexer bundles the different wavelength to one single optical fiber.

Fiber optic lines are transporting the light from location A to B

A WDM demultiplexer is splitting the multiplexed light and transport it to the single receivers for every used wavelength.



Passive WDM multiplexing module



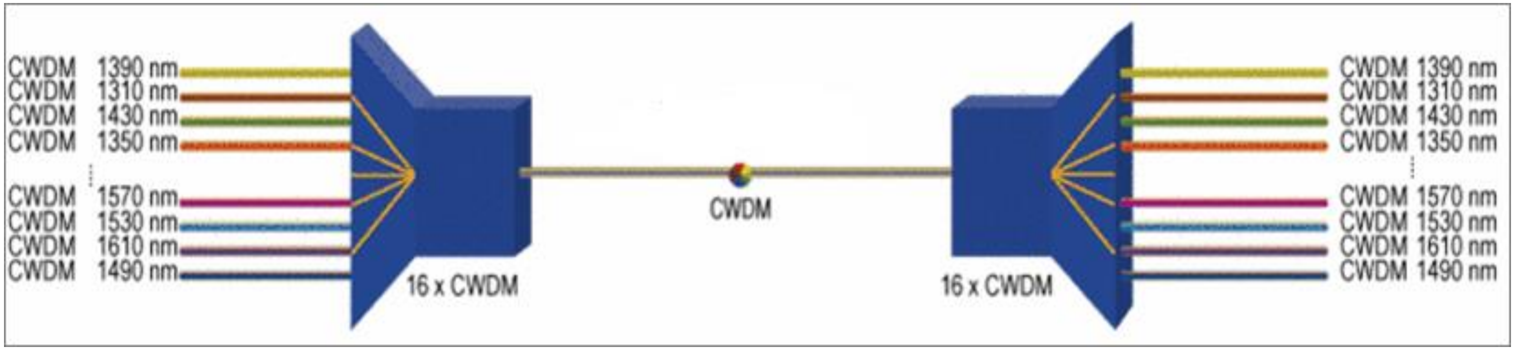
CWDM method

The CWDM "coarse wavelength division multiplexing„ method is also as the DWDM method a multiplexing of different wavelength for optical networks.

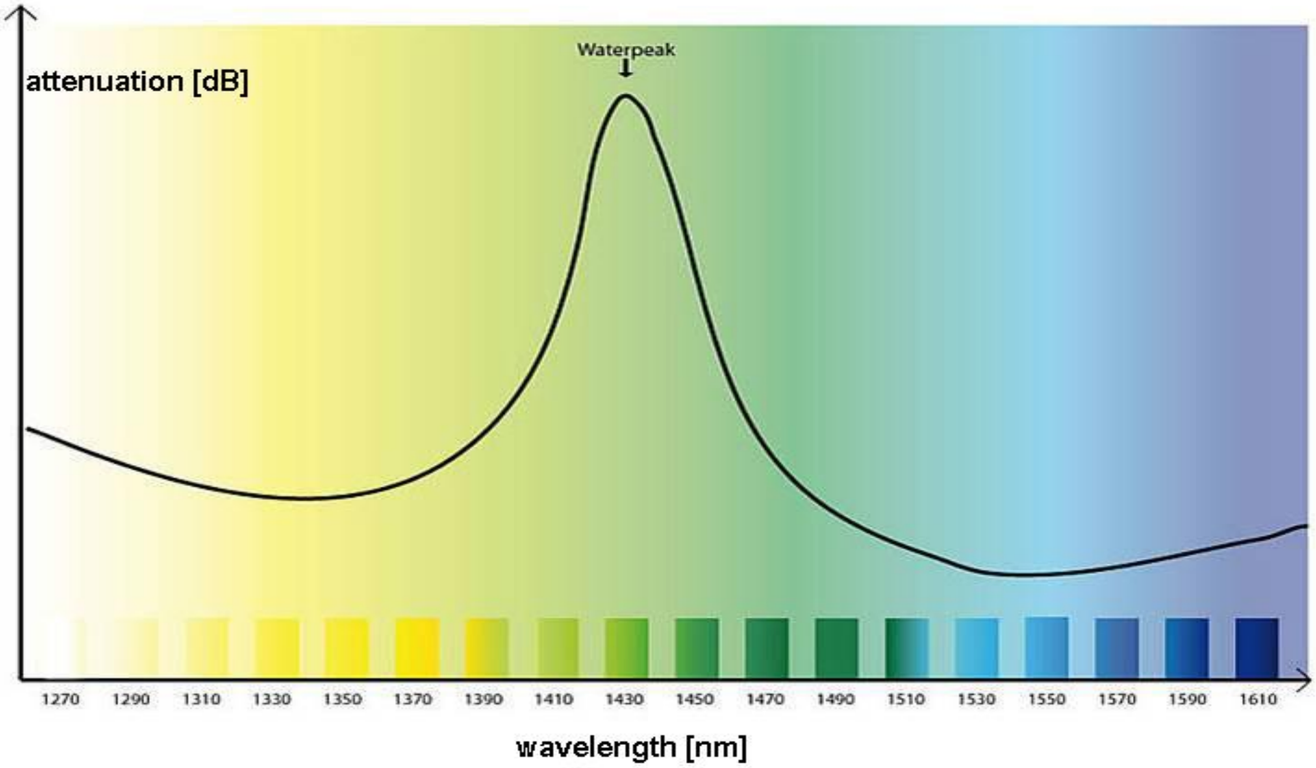
The transmission is using up to 16 channels with bandwidths between 1270nm and 1610nm.

Because of the high channel spacing of 20nm also lower priced Lasers can be used.

The with of the each channel is 13nm. The left over 7nm are used as safety distance to the next channel.



Up to 16 wavelength can be multiplexed to a single optical fiber



CWDM technical details:
ITU-T G.694.2
λ: 1271 nm - 1611 nm
max. 18 channels, 2 channels can not be used because of the waterpeaks
Channel spacing: 20 nm

DWDM (Dense Wavelength Division Multiplexing)

Definition: DWDM is able to transport up to 45 or 90 wavelength on a pair of optical fibers

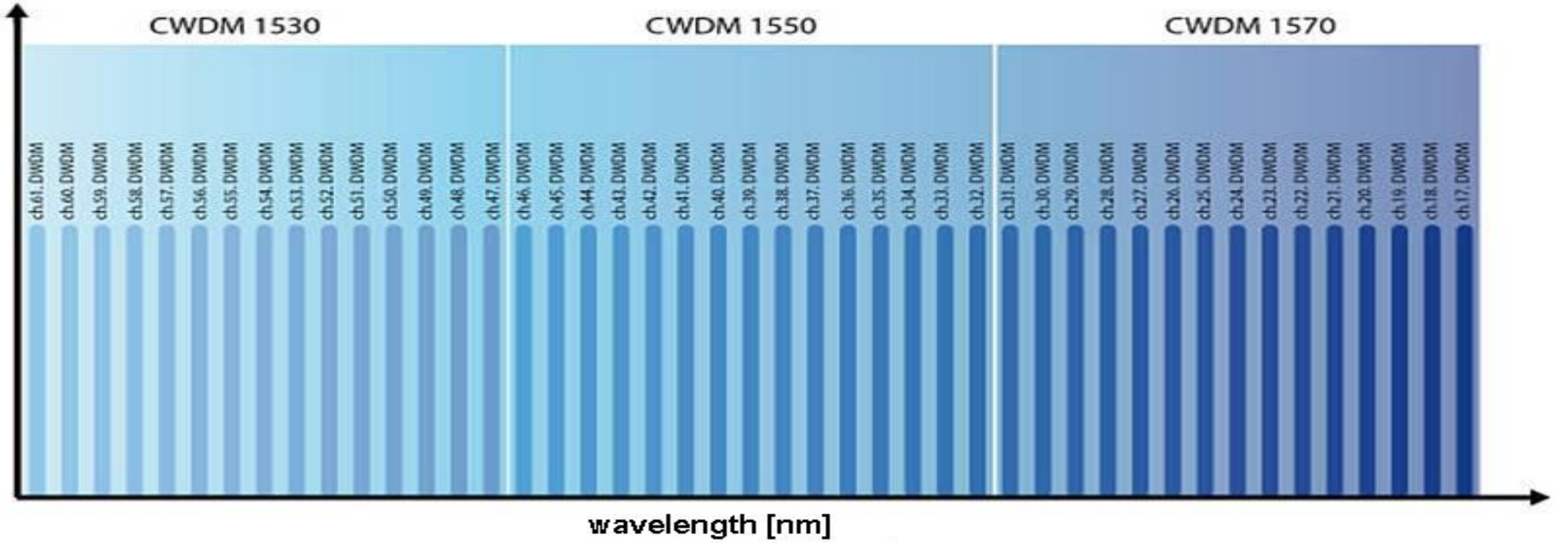
DWDM Highlights

DWDM channel spacing 0,8nm (100 GHz Grid) or 0,4nm (50 GHz Grid)

DWDM range of transmission: More then 1.000 km with optical amplifiers.

Optional integration in already existing CWDM infrastructures possible by using CWDM/DWDM integration.

DWDM Wavelength range from 1528nm (Channel 61) up to 1563nm (Channel 17)



Functionality of DWDM

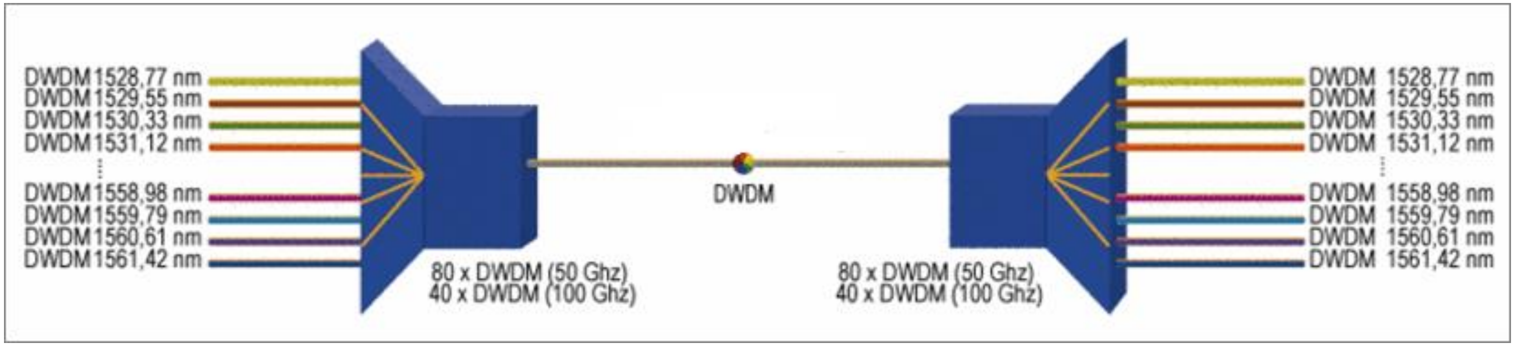
The functionality of DWDM is very similar to the CWDM technology.

Different to CWDM the channel spacing for DWDM is 0,8nm.

Because of this very low channel spacing it is possible to transmit much more information simultaneously. At the moment only the wavelength between 1530nm and 1625nm are used.

DWDM is cascading the wavelength of the CDWM range.

The DWDM technology is very expensive compared to CWDM because of the transceivers that needs to be very precise.



Up to 45 DWDM wavelength (100 GHz Grid) or up to 90 DWDM wavelength (50 GHZ Grid) can be transmitted over a single optical fiber.

DWDM technical details:

ITU-T G.694.1

C-Band λ: 1530 nm - 1565 nm

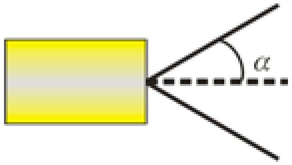
max. 360 channels (12,5 GHz Grid)

L-Band λ: 1565 nm - 1625 nm

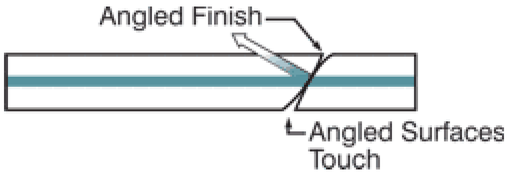
max. 560 channels (12,5 GHz Grid)

Fiber optic technical terms

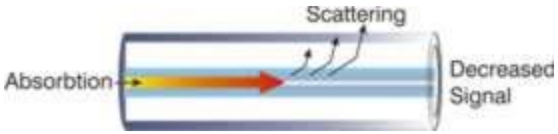
Acceptance Angle
The half-angle of the cone (a) within which incident light is totally internally reflected by the fiber core. It is equal to sin-1(NA).



APC
Abbreviation for angled physical contact. A style of fiber optic connector with a 5 -15 angle on the connector tip for the minimum possible backreflection.



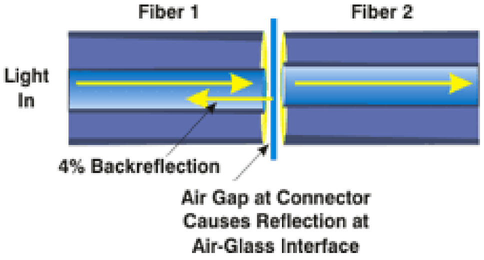
AR Coating
Antireflection coating. A thin, dielectric or metallic film applied to an optical surface to reduce its reflectance and thereby increase its transmittance.



Attenuation
The decrease in signal strength along a fiber optic waveguide caused by absorption and scattering. Attenuation is usually expressed in dB/km.

Backreflection (BR)

A term applied to any process in the cable plant that causes light to change directions in a fiber and return to the source. Occurs most often at connector interfaces where a glass-air interface causes a reflection.



Backscattering

The return of a portion of scattered light to the input end of a fiber; the scattering of light in the direction opposite to its original propagation.

Bandwidth

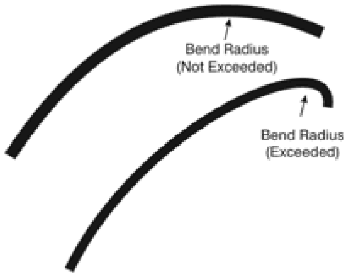
The range of frequencies within which a fiber optic waveguide or terminal device can transmit data or information.

Bandwidth Distance Product

Of an optical fiber, under specified launching and cabling conditions, at a specified wavelength, a figure of merit equal to the product of the fiber’s length and the 3 dB bandwidth of the optical signal. The bandwidth•distance product is usually stated in megahertz • kilometer (MHz•km) or gigahertz•kilometer (GHz•km). It is a useful figure of merit for predicting the effective fiber bandwidth for other lengths, and for concatenated fibers.

Bend Radius

The smallest radius an optical fiber or fiber cable can bend before excessive attenuation or breakage occurs.



Chromatic Dispersion

Reduced fiber bandwidth caused by different wavelengths of light traveling at different speeds down the optical fiber. Chromatic dispersion occurs because the speed at which an optical pulse travels depends on its wavelength, a property inherent to all optical fiber. May be caused by material dispersion, waveguide dispersion, and profile dispersion.

Cladding

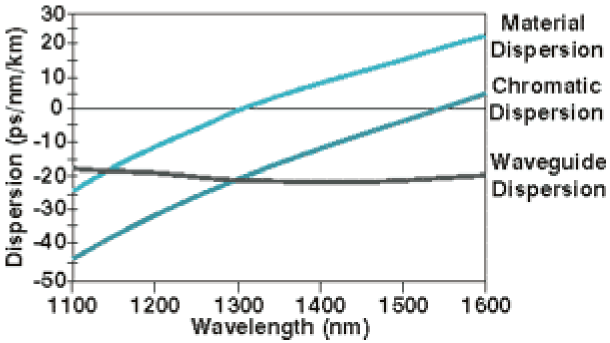
Material that surrounds the core of an optical fiber. Its lower index of refraction, compared to that of the core, causes the transmitted light to travel down the core.

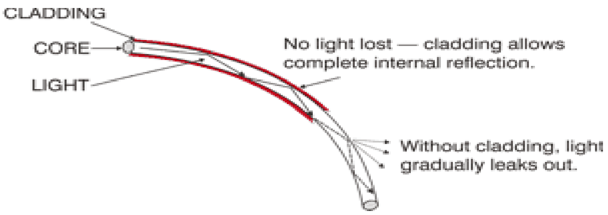
Coating

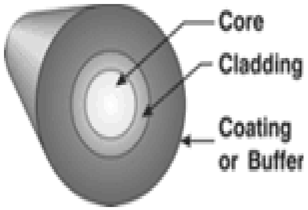
The material surrounding the cladding of a fiber. Generally a soft plastic material that protects the fiber from damage.

Core

The light-conducting central portion of an optical fiber, composed of material with a higher index of refraction than the cladding. The portion of the fiber that transmits light.







Dispersion

The temporal spreading of a light signal in an optical waveguide caused by light signals traveling at different speeds through a fiber either due to modal or chromatic effects.

Dispersion-shifted Fiber (DSF)

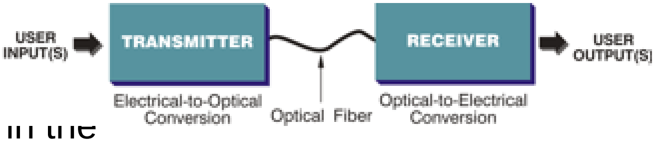
A type of single-mode fiber designed to have zero dispersion near 1550 nm. This fiber type works very poorly for DWDM applications because of high fiber nonlinearity at the zero-dispersion wavelength.

FC/PC

A threaded optical connector that uses a special curved polish on the connector for very low backreflection. Good for single-mode or multimode fiber.

Fiber Optic Link

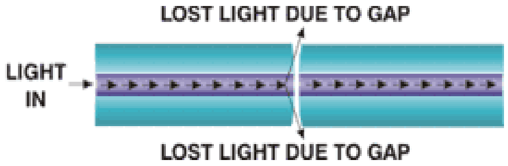
A transmitter, receiver, and cable assembly that can transmit information between two points.



Fresnel Reflection Loss

Reflection losses at the ends of fibers caused by differences in the refractive index between glass and air. The maximum reflection caused by a perpendicular air-glass interface is about 4% or about -14 dB.

Gap Loss
Loss resulting from the end separation of two axially aligned fibers.

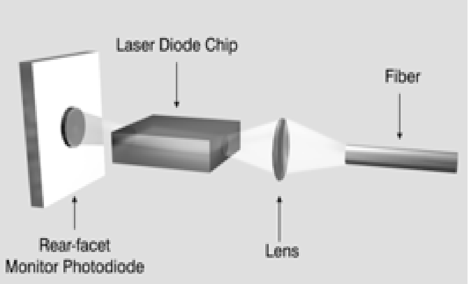


Insertion Loss
The loss of power that results from inserting a component, such as a connector, coupler (illustrated), or splice, into a previously continuous path.

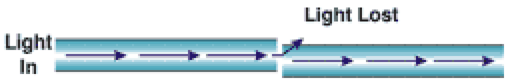
L-Band
The wavelength range between 1570 nm and 1610 nm used in some CWDM and DWDM applications.

Laser
Acronym for light amplification by stimulated emission of radiation. A light source that produces, through stimulated emission, coherent, near monochromatic light

Laser Diode (LD)
A semiconductor that emits coherent light when forward biased.

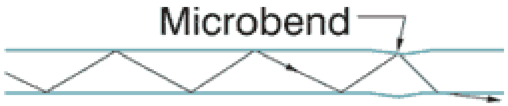


Lateral Displacement Loss
The loss of power that results from lateral displacement of optimum alignment between two fibers or between a fiber and an active device.



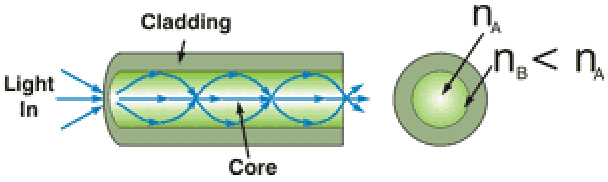
Material Dispersion
Dispersion resulting from the different velocities of each wavelength in a material.

Microbending
Mechanical stress on a fiber that introduces local discontinuities, which results in light leaking from the core to the cladding by a process called mode coupling.



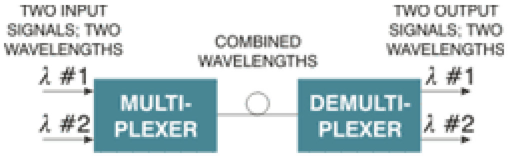
Mode Field Diameter (MFD):
A measure of distribution of optical power intensity across the end face of a single-mode fiber.

Multimode (MM) Fiber
An optical fiber that has a core large enough to propagate more than one mode of light The typical diameter is 62.5 micrometers.



Multiple Reflection Noise (MRN)
The fiber optic receiver noise resulting from the interference of delayed signals from two or more reflection points in a fiber optic span. Also known as multipath interference.

Multiplexer
A device that combines two or more signals into one output.



nm
Abbreviation for nanometer. One billionth of a meter or 10^{-9} meters.

Noise Equivalent Power (NEP)
The noise of optical receivers, or of an entire transmission system, is often expressed in terms of noise equivalent optical power

Noise Figure (NF)
The ratio of the output signal-to-noise ratio to the input signal-to-noise ratio for a given element in a transmission system. Used for optical and electrical components.

Non Dispersion-shifted Fiber (NDSF)
The most popular type of single-mode fiber deployed. It is designed to have a zero-dispersion wavelength near 1310 nm.

Non Zero-dispersion-shifted Fiber (NZ-DSF)

A dispersion-shifted single-mode fiber that has the zero-dispersion wavelength near the 1550 nm window, but outside the window actually used to transmit signals. This strategy maximizes bandwidth while minimizing fiber nonlinearities.

Optical Amplifier

A device that amplifies an input optical signal without converting it into electrical form. The best developed are optical fibers doped with the rare earth element, erbium.

Optical Return Loss (ORL)

The ratio (expressed in dB) of optical power reflected by a component or an assembly to the optical power incident on a component port when that component or assembly is introduced into a link or system

OTDR (Optical Time Domain Reflectometer)

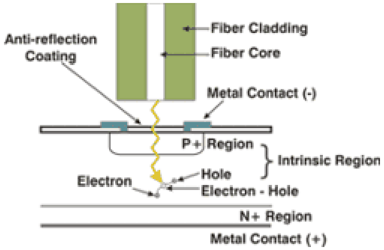
An instrument that locates faults in optical fibers or infers attenuation by backscattered light measurements.

Photodiode (PD)

A semiconductor device that converts light to electrical current.

Photodetector

An optoelectronic transducer such as a PIN photodiode (illustrated) or avalanche photodiode. In the case of the PIN diode, it is so named because it is constructed from materials layered by their positive, intrinsic, and negative electron regions.

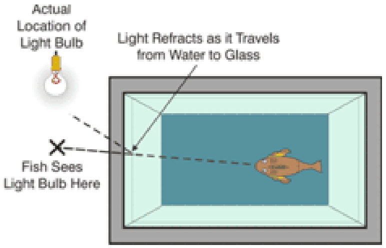


Plastic Fiber

An optical fiber having a plastic core and plastic cladding.

Refraction

The changing of direction of a light wave in passing through a boundary between two dissimilar media, or in a graded-index medium where refractive index is a continuous function of position.



Refractive Index

A property of optical materials that relates to the speed of light in the material versus the speed of light in a vacuum.

Refractive Index Gradient

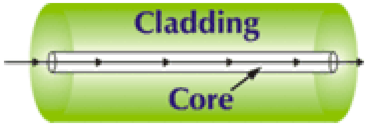
The description of the value of the refractive index as a function of distance from the optical axis along an optical fiber diameter. Also called refractive index profile.

S-Band

The wavelength region between 1485 nm and 1520 nm used in some CWDM and DWDM applications.

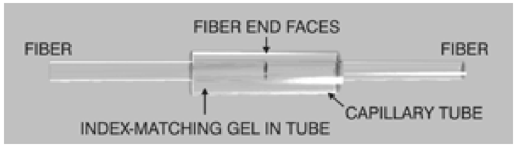
Single-mode (SM) Fiber

A small-core optical fiber through which only one mode will propagate. The typical diameter is 8-9 microns.



Splice

A permanent connection of two optical fibers through fusion or mechanical means.



Transceiver

A device that performs, within one chassis, both telecommunication transmitting and receiving functions.

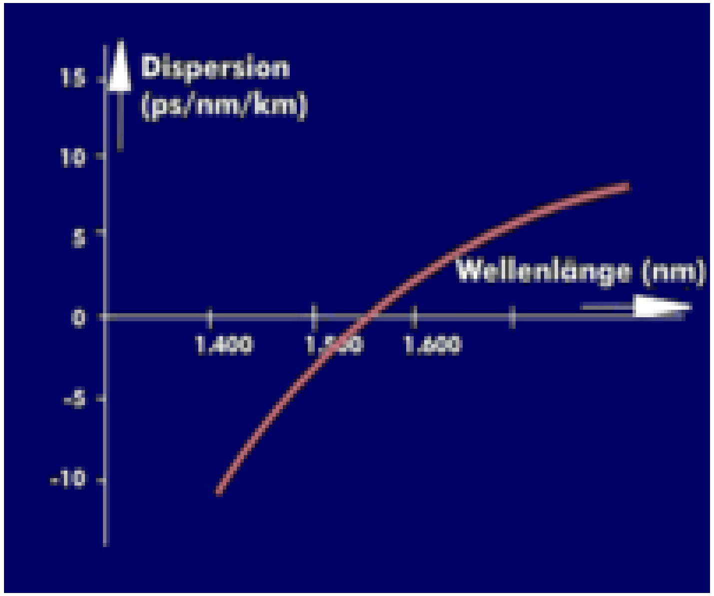
Zero-dispersion Slope

In single-mode fiber, the rate of change of dispersion with respect to wavelength, at the fibers zero-dispersion wavelength.

Zero-dispersion Wavelength (l0)

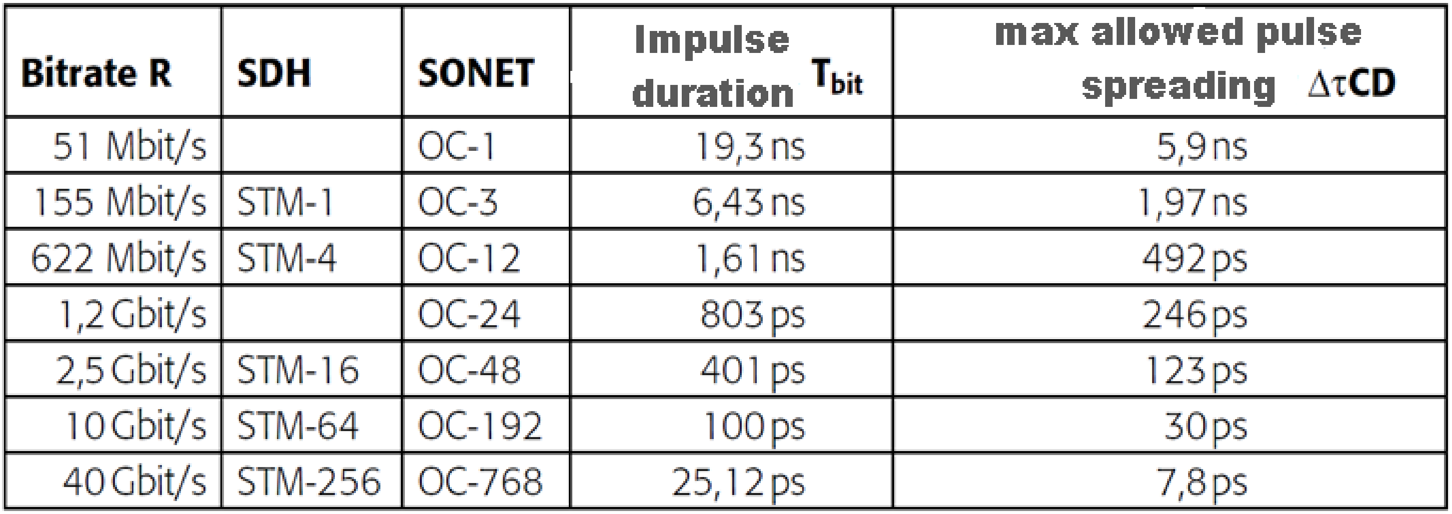
In a single-mode optical fiber, the wavelength at which material dispersion and waveguide dispersion cancel one another. The wavelength of maximum bandwidth in the fiber. Also called zero-dispersion point.

Dispersion-shifted fiber (**DSF**) is a type of optical fiber made to optimize both low dispersion and low attenuation to compensate signal corruption caused by optical amplifiers and dispersion.



Dispersion Shifted Fiber is a type of single-mode optical fiber with a core-clad index profile tailored to shift the zero-dispersion wavelength from the natural 1300 nm in silica-glass fibers to the minimum-loss window at 1550 nm. The group velocity or *intramodal* dispersion which dominates in single-mode fibers includes both material and waveguide dispersion. Waveguide dispersion can be made more negative by changing the index profile and thus be used to offset the fixed material dispersion, shifting or flattening the overall intramodal dispersion. This is advantageous because it allows a communication system to possess both low dispersion and low attenuation. However, when used in wavelength division multiplexing systems, dispersion-shifted fibers can suffer from four-wave mixing which causes intermodulation of the independent signals. As a result nonzero dispersion shifted fiber is often used

Maximum allowed impulse spreading caused by chromatic dispersion as a function of the bit-rate



Bitrate R	**SDH**	**SONET**	**Impulse duration T_{bit}**	**max allowed pulse spreading $\Delta\tau CD$**
51 Mbit/s		OC-1	19,3 ns	5,9 ns
155 Mbit/s	STM-1	OC-3	6,43 ns	1,97 ns
622 Mbit/s	STM-4	OC-12	1,61 ns	492 ps
1,2 Gbit/s		OC-24	803 ps	246 ps
2,5 Gbit/s	STM-16	OC-48	401 ps	123 ps
10 Gbit/s	STM-64	OC-192	100 ps	30 ps
40 Gbit/s	STM-256	OC-768	25,12 ps	7,8 ps

Cleaning of fiber connectors

Contents:

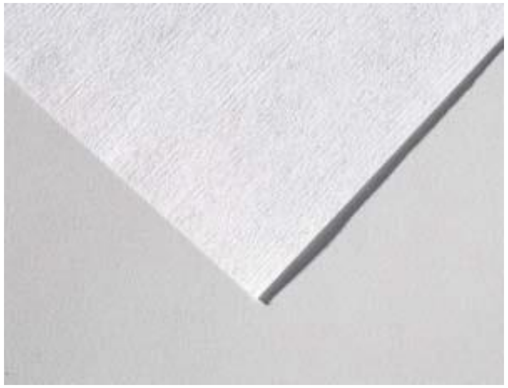
- List of materials
- Cleaning of the connector surface with a cloth
- How to use a cleaning cassette
- How to use an In-Ferrule Cleaner
- Cleaning of optical couplers
- Microscopically view of a connector before and after cleaning
- Cleaning of a Neutric opticalCON connector
- Detailed list of materials

List of materials

Electro Wash PX cleaner (not hygroscopic) or Isopropanol

Cleaning cassette for connectors,
type NTT Reel Cleaner

Econowipes cleaning cloth (lint-free)



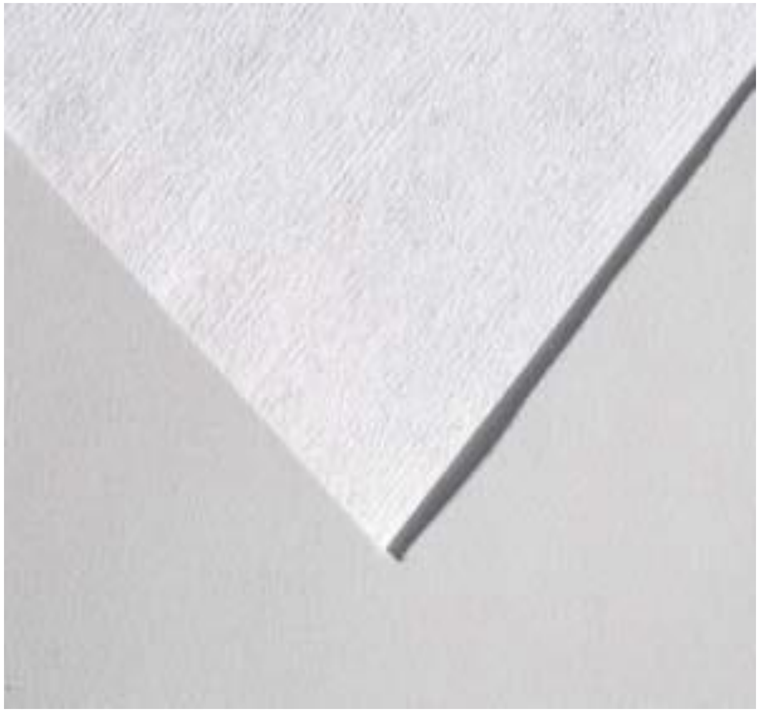
List of materials

In-Ferrule cleaner,
type IBC 2,5mm or 1,25mm

Handmicroscope
(min. 200x optical enlargement)

Cleaning sticks for 2,5mm ferrules

Cleaning of the connector surface with a cloth



Dry cleaning of connectors (without liquid)

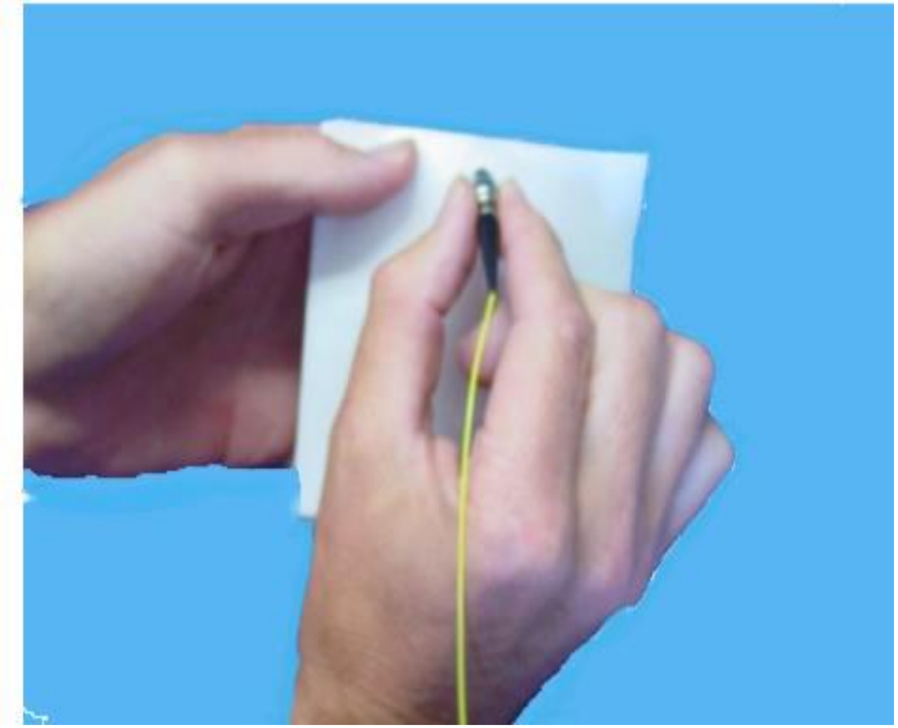
T**o clean a “straight” fiber connector** you need to stack several Econowipes cleaning cloths on an even surface. Hold the connector in a 90° angle to the cleaning cloth surface.
Pull the connector evenly across the cloth.
Don‘t apply strong pressure – light pressure leads to better cleaning results! Never use the same part of the cloth surface twice. All of the cloth surface can be used.

Don‘t work with a typical figure 8 movement when moving the connector across the cloth.

Don‘t clean it with circular movements either.

Check the connector under the microscope after cleaning it. If necessary, repeat the procedure.

Cleaning of the connector surface with a cloth



Dry cleaning of APC connectors (without liquid)

Put several Econowipes cleaning cloths in the palm of your hand and hold them with your thumb. Find the angled surface at the tip of the connector and pull this across the surface of the cloth along your index finger.

Apart from this the same rules apply as with the “straight” fiber connector.

Cleaning of connectors with a moist cloth …

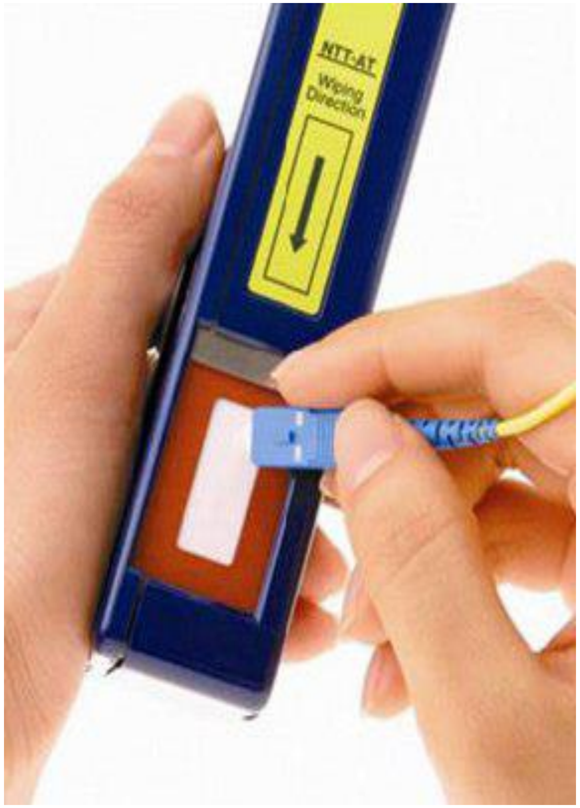
… using Electro Wash PX or Isopropanol.

Applicable for cleaning a “straight” fiber connector or an APC connector.

The principle is similar to the dry cleaning, but:

Moisten a part of the cloth with the liquid. Pull the connector across the cloth starting at the moist spot moving to the dry part. Let the connector dry off completely and the control it under the microscope. If necessary repeat the procedure.

How to use a cleaning cassette



Cleaning of a "straight" fiber connector

Press and hold the green button to open the cleaning surface. Hold the connector in a 90° angle to the cleaning surface. Pull the connector evenly in a straight line across the cleaning surface. Don't apply strong pressure – light pressure leads to better cleaning results! Never use the same part of the cleaning surface twice. All of the surface can be used.

Don't work with a typical figure 8 movement when moving the connector across the cloth. Don't clean it with circular movements either.

Check the connector under the microscope after cleaning it. If necessary, repeat the procedure.

Cleaning of APC connectors

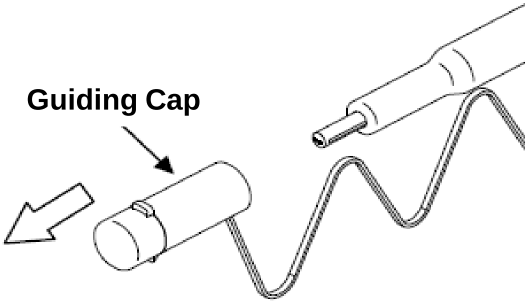
Find the angled surface at the tip of the connector and pull this across the cleaning surface.

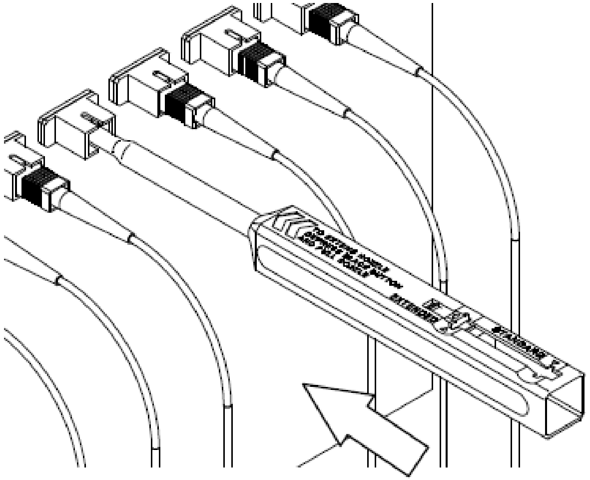
The same rules apply as with the "straight" fiber connector.

The use of a cleaning cassette is only recommended for dry cleaning.

How to use an In-Ferrule cleaner

Always use the In-Ferrule cleaner matching the connector (2.5mm or 1.25mm diameter)





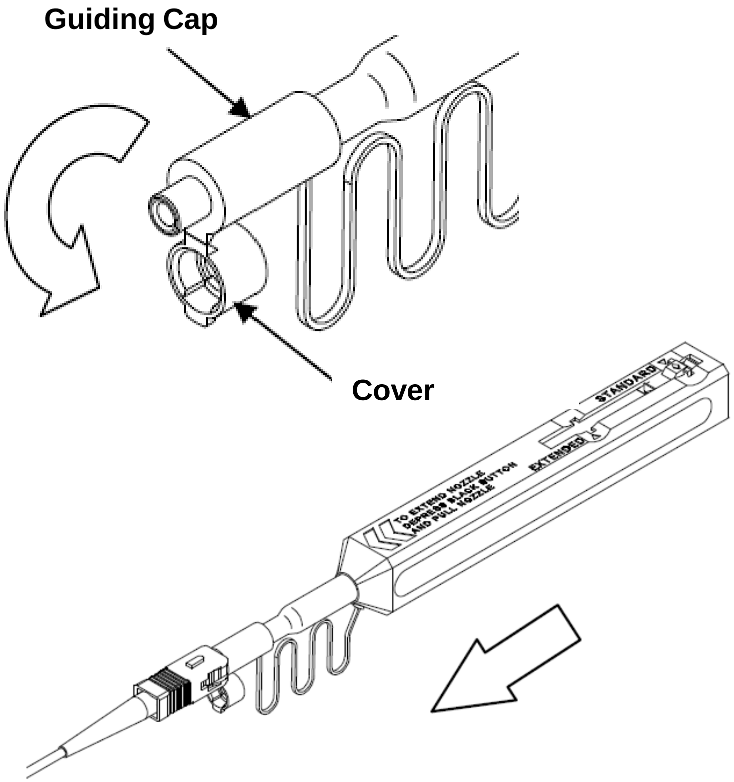
Cleaning of integrated connector surfaces in patch fields, using the IBC In-Ferrule cleaner.

Remove the cap from the tip of the cleaner. Slide the cleaner tip into the connector. In high-density patch fields you may need to utilize the tip extension. Push the cleaner into the connector until you hear a „click“.

ATTENTION:
Make sure you don‘t twist the cleaner while inserting the cleaning tip into the connector. Don‘t apply too much pressure as this may cause damage to the connector, the coupler or the In-Ferrule cleaner. If the tip seems to block during insertion, please remove it and make sure there are no larger dirt particles inside the coupler blocking the tip.

How to use an In-Ferrule cleaner

The IBC In-Ferrule cleaner can also be used to clean unmounted connectors.



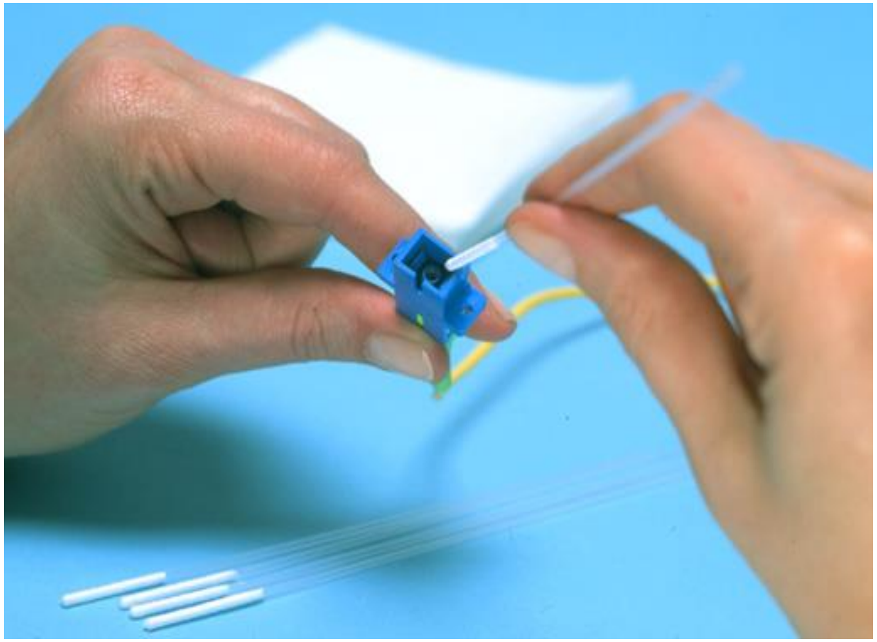
Cleaning a connector with the IBC In-Ferrule cleaner

Remove the cover of the guiding cap of the In-Ferrule cleaner. Stick the fiber connector onto the guiding cap and press the two components together until you hear a „click“.

Apart from this, the same rules apply as with mounted fiber connectors.

Cleaning of optical couplers

Use cleaning sticks matching the coupler (2.5mm or 1.25mm diameter)



Dry cleaning of fiber couplers (without liquid)

Carefully insert the soft end of the cleaning stick into the coupler until it touches the optical surface. Turn the stick 4 to 5 times counter-clockwise with slight pressure.

Repeat the procedure if necessary.

Cleaning of optical couplers

Use cleaning sticks matching the coupler (2.5mm or 1.25mm diameter)

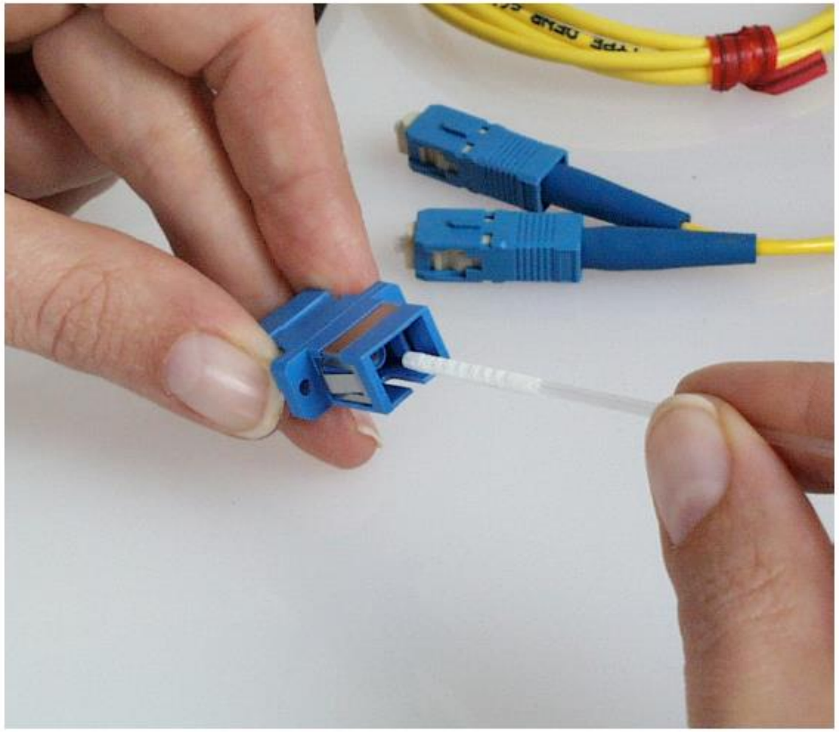
Wet cleaning of fiber couplers
(with Elektro Wash PX or Isopropanol)

Use only as much cleaner as necessary. Don‘t spray the cleaner directly onto the cleaning stick. Fold a cleaning cloth into the cap of the cleaner can or into a similar container and spray a bit of the liquid onto the cloth.

Moisten the cleaning stick by dabbing it onto the wet spot on the cloth.

Cleaning of optical couplers

Use cleaning sticks matching the coupler (2.5mm or 1.25mm diameter)



Wet cleaning of fiber couplers
(with Elektro Wash PX or Isopropanol)

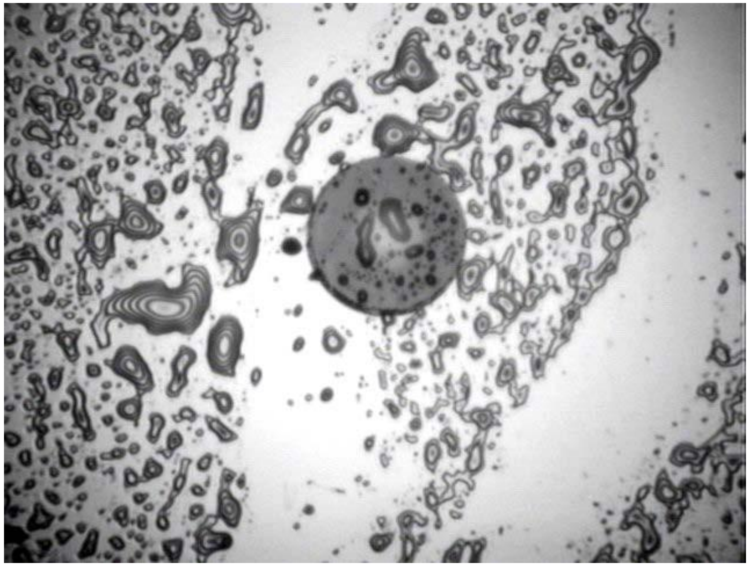
Carefully insert the soft end of the cleaning stick into the coupler until it touches the optical surface. Clean the coupler as described previously (dry cleaning).

Repeat the procedure if necessary.

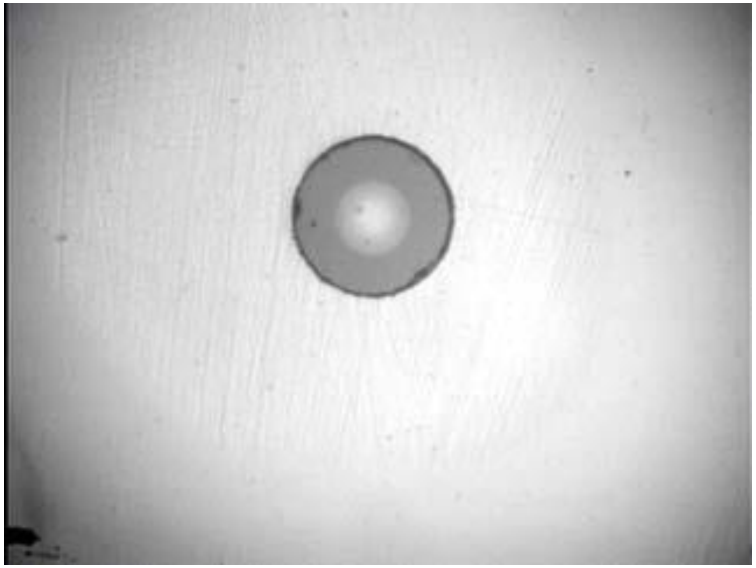
Microscopically view of a connector

Example: Multi-Mode connector

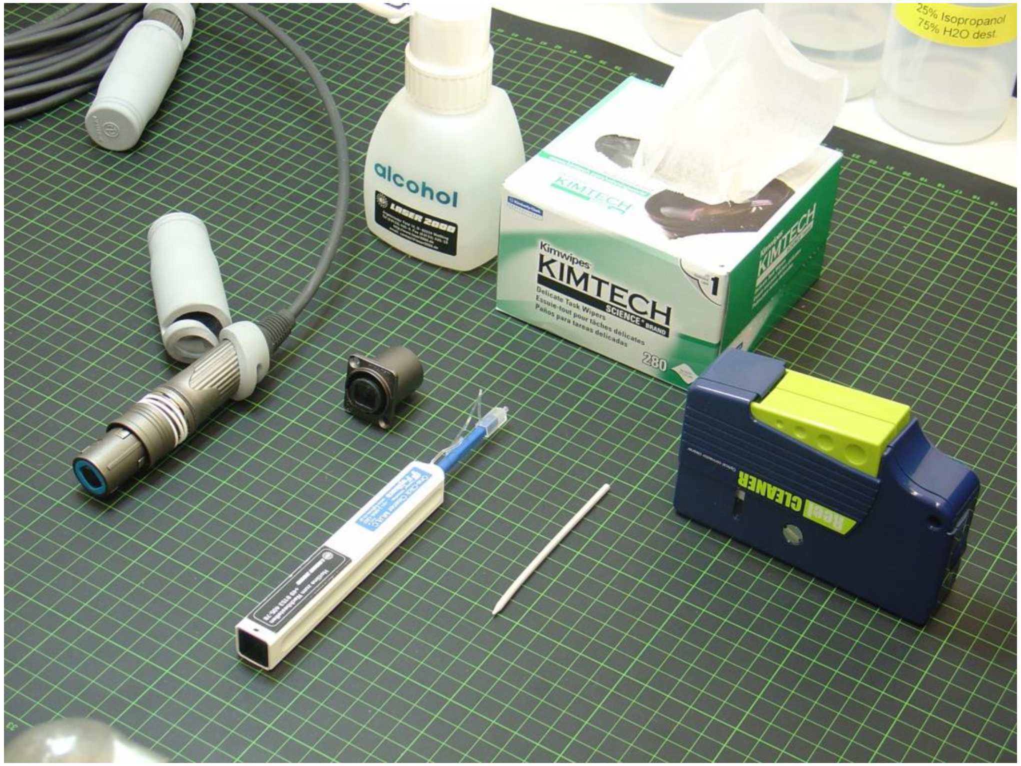
Before cleaning …



… after cleaning



Cleaning of a Neutric opticalCON connector



Cleaning of a Neutric opticalCON connector

Pull the toothed plate back and unscrew the rear strain-relief cover. While doing this, don‘t twist or turn the actual connector enclosure (front).

Cleaning of a Neutric opticalCON connector

Remove the connector enclosure.

Cleaning of a Neutric opticalCON connector

Clean the connector tip and the ferrules using a lint-free cleaning cloth moistened with Elektro Wash PX or Isopropanol.

Cleaning of a Neutric opticalCON connector

Clean the ferrule tips using a cleaning cassette.

Pull the ferrules across the white strip applying light pressure.

Cleaning of a Neutric opticalCON connector

Alternatively the ferrule tips can also be cleaned using an In-Ferrule cleaner.

Light pressure applied to the end of the connector will open the dust protection cap and give access to the ferrules.

Set the In-Ferrule cleaner onto the tip of a ferrule and push it down to clean the ferrule. Repeat this for all ferrules inside.

Cleaning of a Neutric opticalCON connector

To clean the socket, push back the dust protection cap with light pressure.

The ferrule jackets with the LC connectors on the rear are now accessible and can be cleaned with the In-Ferrule cleaner.