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Optical Fibers basics

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South-East Europe Fibre Infrastructure
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- Basics of optical fiber transmission
- Fiber Types
- Optical Fiber Impairments
- Fiber standards
- Advantages of fiber optic transmission
- Bibliography



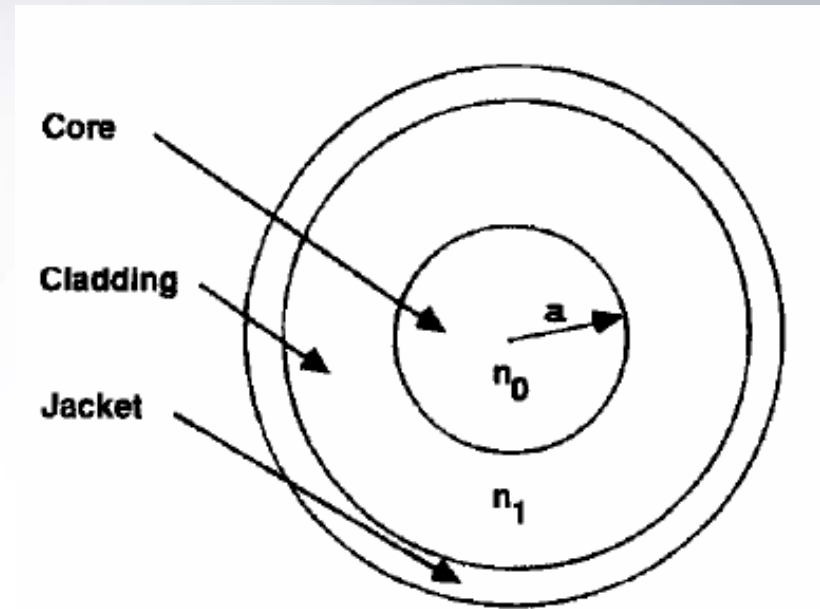
Basics of optical fiber transmission I



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- What is an optical fiber?
 - A glass or plastic fiber that has the ability to guide light along its axis.
- A fiber cable consists of three layers:
 - core,
 - cladding,
 - jacket.



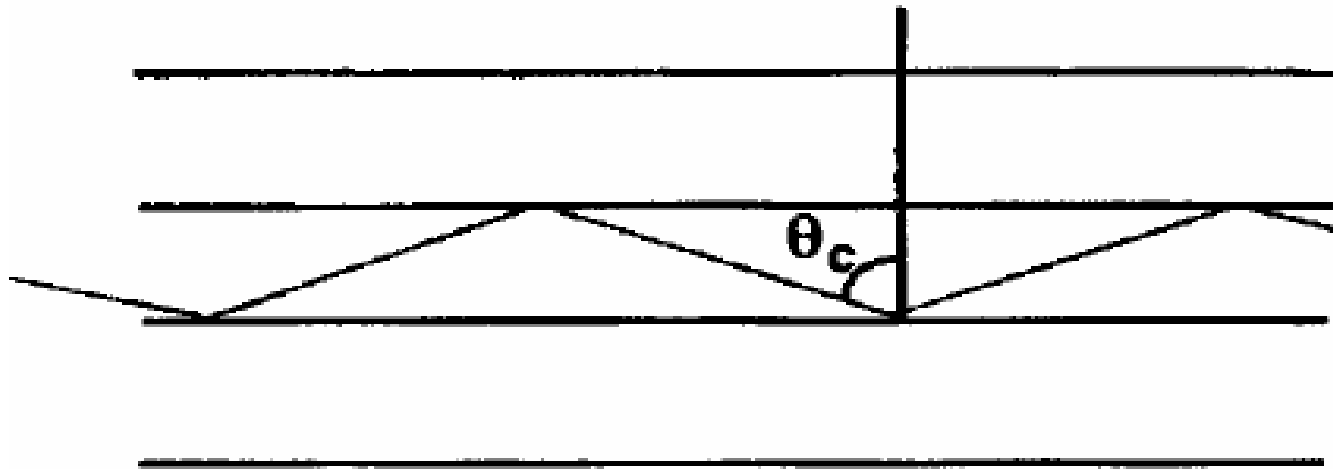
Basics of optical fiber transmission II



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- Total Internal Reflection: when $\theta_c \geq \sin^{-1}(n_1/n_0)$ then the light is totally reflected in the core, where n_0, n_1 refractive index of the core and cladding respectively.



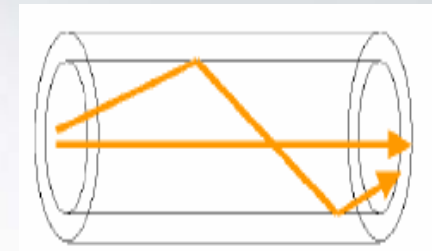
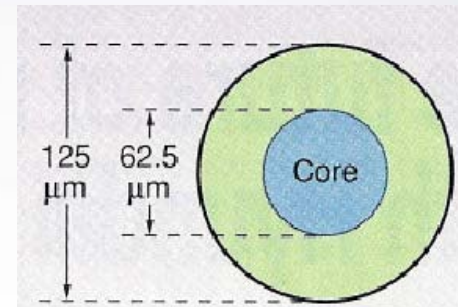
Fiber Types



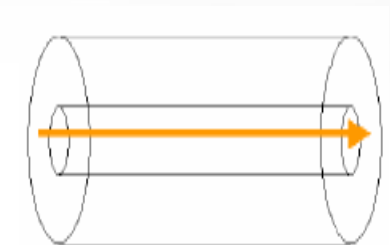
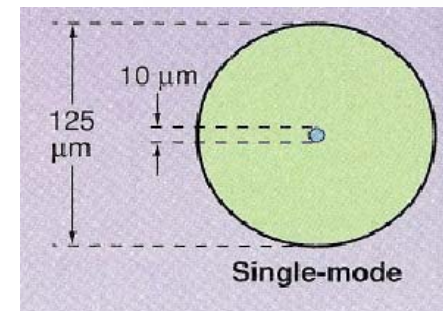
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- Multi-Mode: supports hundreds paths for light.



- Single-Mode: supports a single path for light



Multi-Mode vs Single-Mode



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	Multi-Mode	Single-Mode
<i>Modes of light</i>	Many	One
<i>Distance</i>	Short	Long
<i>Bandwidth</i>	Low	High
<i>Typical Application</i>	Access	Metro, Core



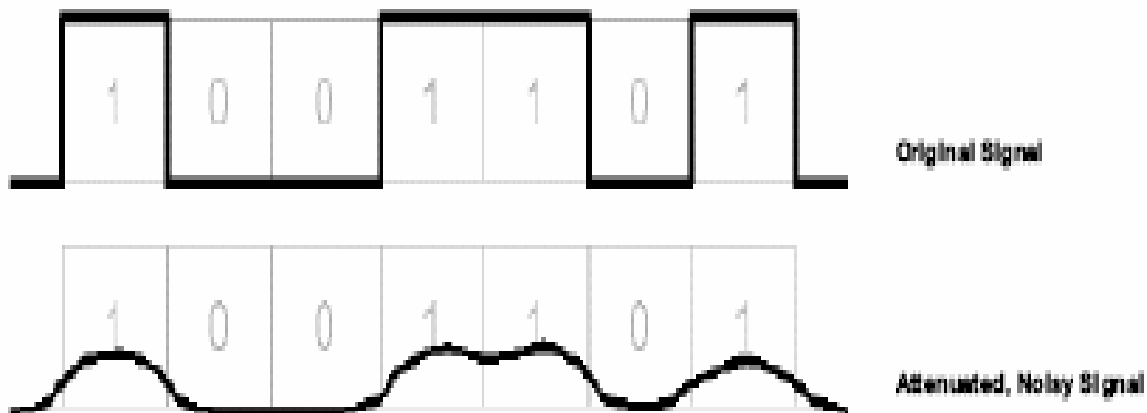
Attenuation



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- It is the reduction of light power over the length of the fiber.
 - It's mainly caused by scattering.
 - It depends on the transmission frequency.
 - It's measured in dB/km ($dB = 10\log_{10}(P_{out}/P_{in})$)



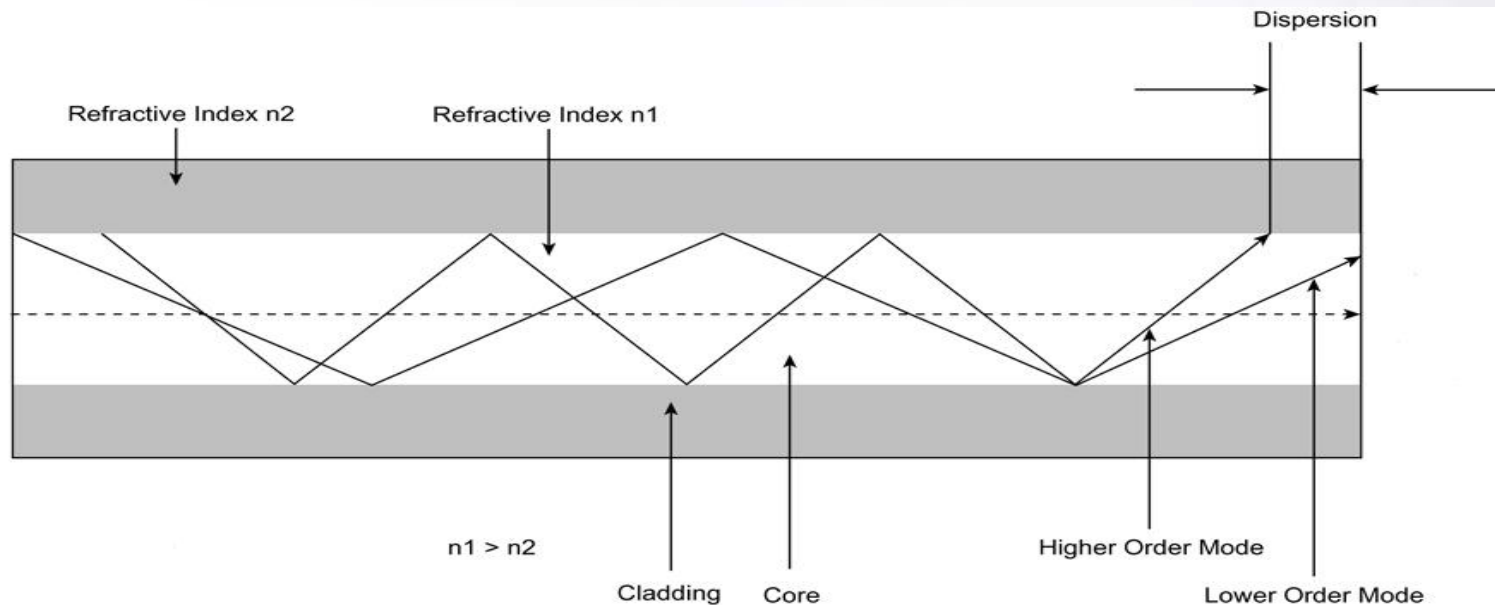
Multimode Dispersion



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- Light rays are transmitted from the source at a variety of angles and arrive at the receiver at different times.



Source www.cisco.com



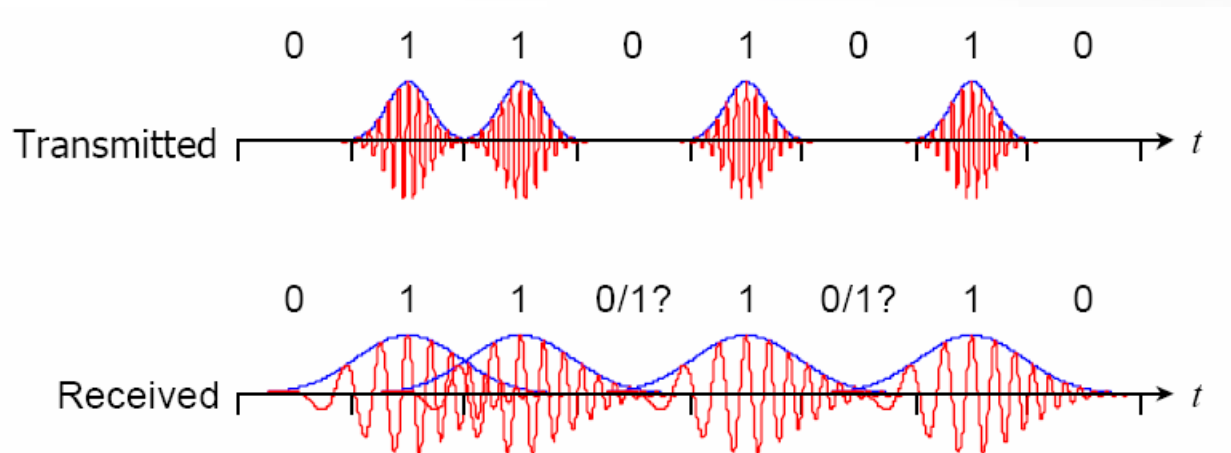
Chromatic Dispersion (CD)



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- Light from lasers consists of a range of wavelengths, each of which travels at a slightly different speed. This results to light pulse spreading over time.
 - It's measured in psec/nm/km.
- The chromatic dispersion effects increase for high rates.



Source www.teraxion.com



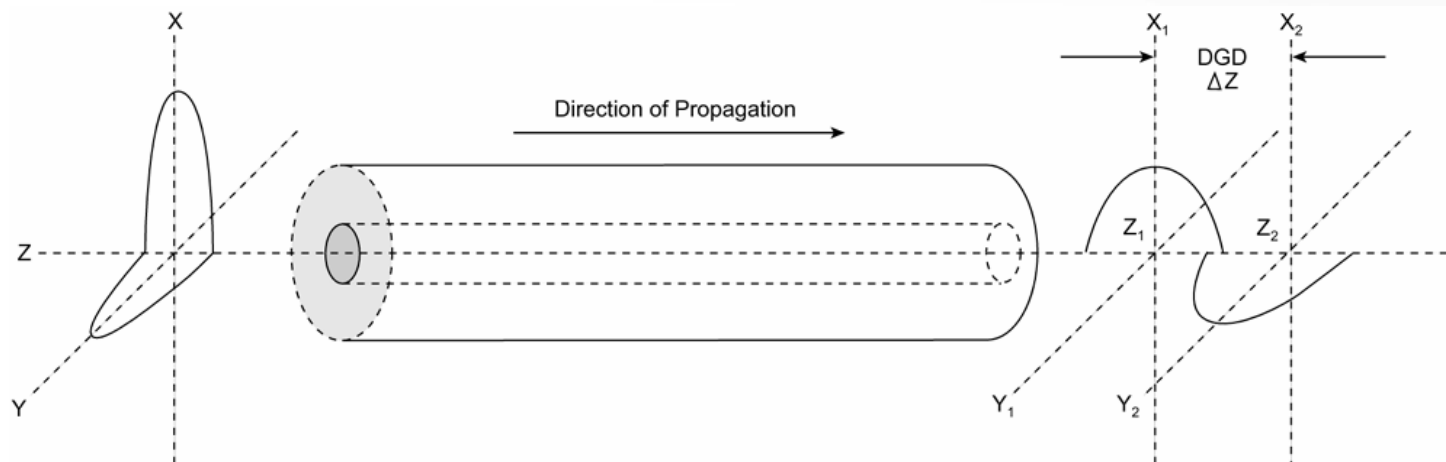
Polarization Mode Dispersion (PMD)



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- Single-mode fibers support two orthogonal polarizations of the transmitted signal. Polarization modes travel with different speeds resulting in dispersion.
 - It's measured in ps / \sqrt{km}
- This phenomenon is evident at bit rates of 10Gbps or more



Transmission Bands



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- Optical transmission is conducted in wavelength regions, called "bands".
- Commercial DWDM systems typically transmit at the C-band
 - Mainly because of the Erbium-Doped Fiber Amplifiers (EDFA).
- Commercial CWDM systems typically transmit at the S, C and L bands.
- ITU-T has defined the wavelength grid for xWDM transmission
 - G.694.1 recommendation for DWDM transmission, covering S, C and L bands.
 - G.694.2 recommendation for CWDM transmission, covering O, E, S, C and L bands.

<i>Band</i>	<i>Wavelength (nm)</i>
<i>O</i>	1260 – 1360
<i>E</i>	1360 – 1460
<i>S</i>	1460 – 1530
<i>C</i>	1530 – 1565
<i>L</i>	1565 – 1625
<i>U</i>	1625 – 1675



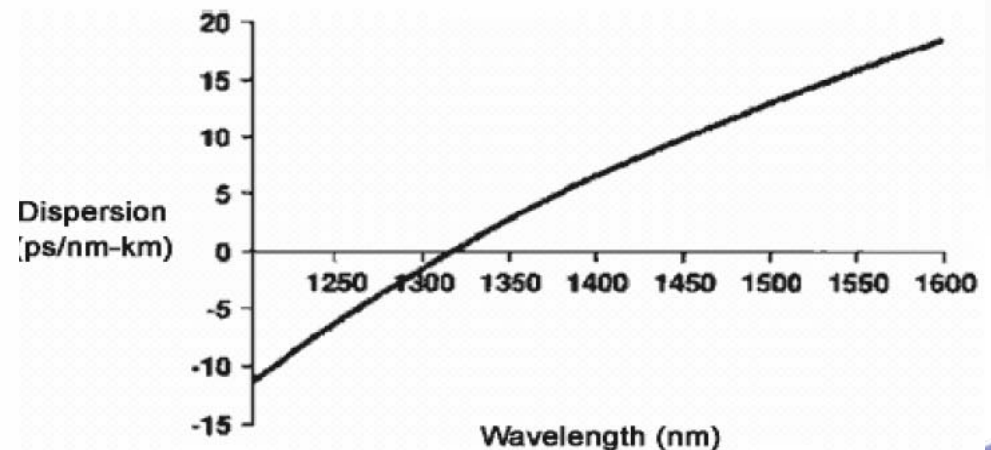
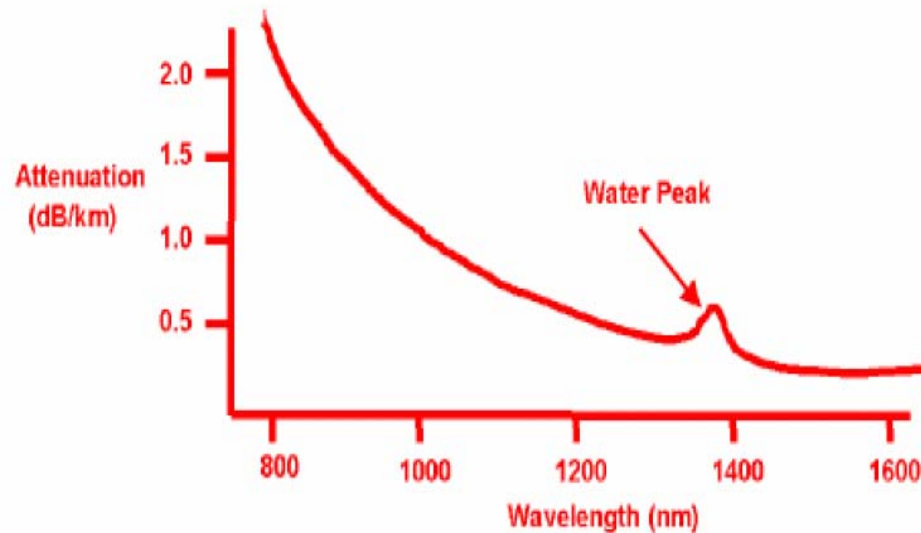
Single Mode Fiber Standards I



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- ITU-T G.652 – standard Single Mode Fiber (SMF) or Non Dispersion Shifted Fiber (NDSF).
 - The most commonly deployed fiber (95% of worldwide deployments).
- “Water Peak Region”: it is the wavelength region of approximately 80 nanometers (nm) centered on 1383 nm with high attenuation.

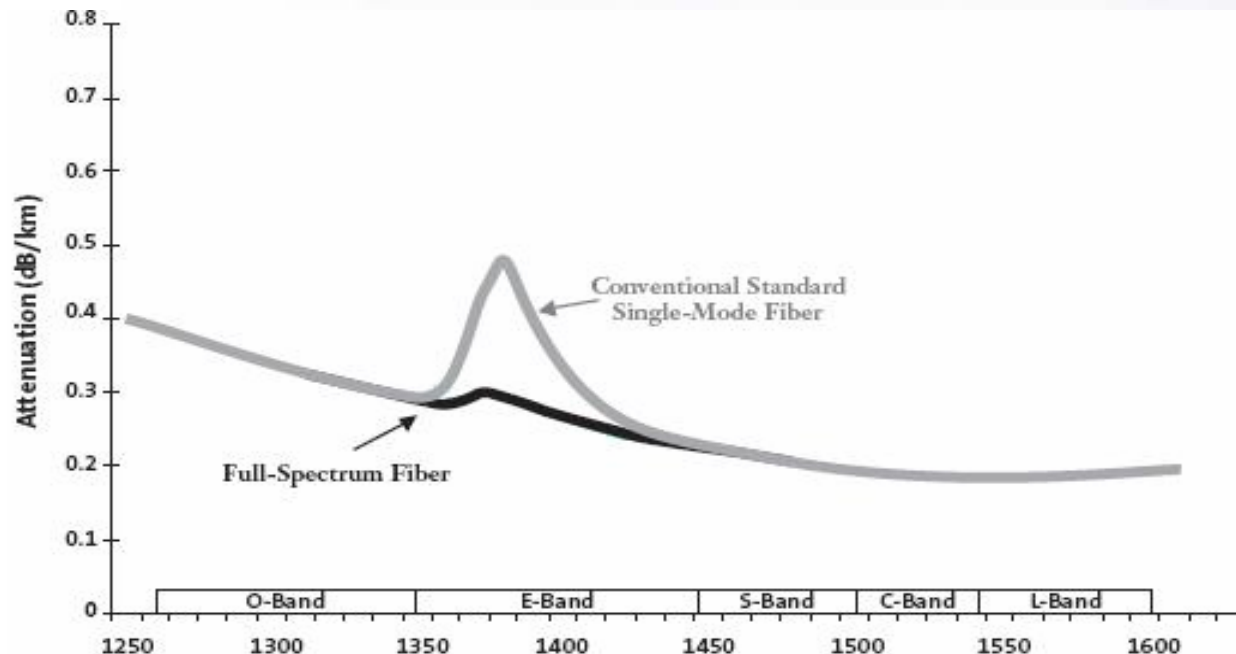


Single Mode Fiber Standards II



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- ITU-T G.652c - Low Water Peak Non Dispersion Shifted Fiber.



Source www.corning.com

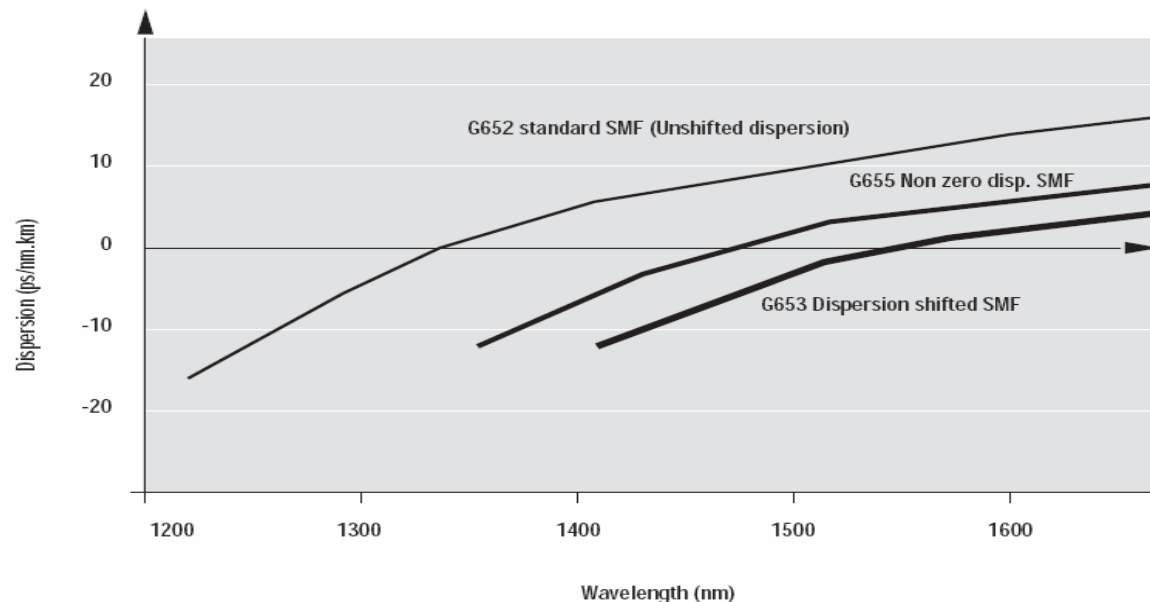


Single Mode Fiber Standards III



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- ITU-T G.653 – Dispersion Shifted Fiber (DSF)
 - It shifts the zero dispersion value within the C-band.
 - Channels allocated at the C-band are seriously affected by noise due to nonlinear effects (Four Wave Mixing).



Single Mode Fiber Standards IV



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- ITU-T G.655 – Non Zero Dispersion Shifted Fiber (NZDSF)
 - Small amount of chromatic dispersion at C-band: minimization of nonlinear effects
- Optimized for DWDM transmission (C and L bands)



Single Mode Fiber Standards V



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ITU-T Standard	Name	Typical Attenuation value (C-band)	Typical CD value (C-band)	Applicability
G.652	standard Single Mode Fiber	0.25dB/km	17 ps/nm-km	OK for xWDM
G.652c	Low Water Peak SMF	0.25dB/km	17 ps/nm-km	Good for CWDM
G.653	Dispersion-Shifted Fiber (DSF)	0.25dB/km	0 ps/nm-km	Bad for xWDM
G.655	Non-Zero Dispersion-Shifted Fiber (NZDSF)	0.25dB/km	4.5 ps/nm-km	Good for DWDM



Fiber optic transmission advantages



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- Really broadband medium.
- The fiber is immune to virtually all kinds of interference.
- A fiber optic cable is much smaller and lighter in weight than a wire or coaxial cable with similar information carrying capacity.
- Fiber optic cable is ideal for secure communications.
- Low production cost (~euro/km)





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- "Optical Switching and Networking Handbook", Regis J. Bates, McGraw-Hill, 2001.





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Thanks!!!

