

Key Parameters when  
Selecting Dark Fibres  
&  
The Nordic Fibre Experience

# Key technical fibre parameter and other factors when shopping for fibre

A – Attenuation at especially 1550nm

CMD – Chromatic Mode Dispersion

PMD – Polarisation Mode Dispersion

Non-Linearity: Function of power and Fibre properties

FWM – Four Wave Mixing

SPM – Self Phase Modulation

XPM – Cross Phase Modulation

SRS – Stimulated Raman Scattering

SBS – Stimulated Brillouin Scattering

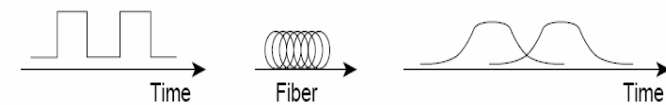
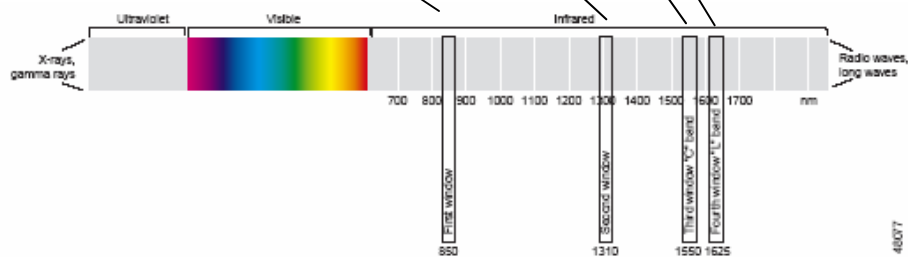
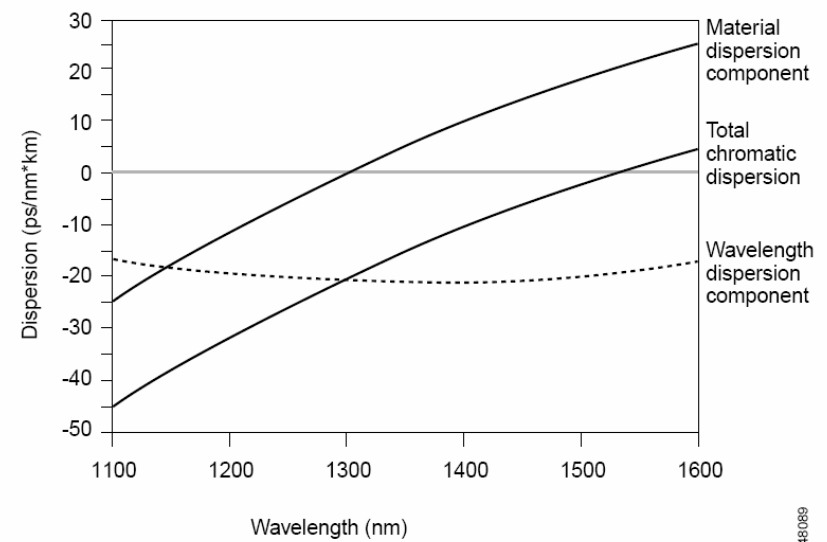
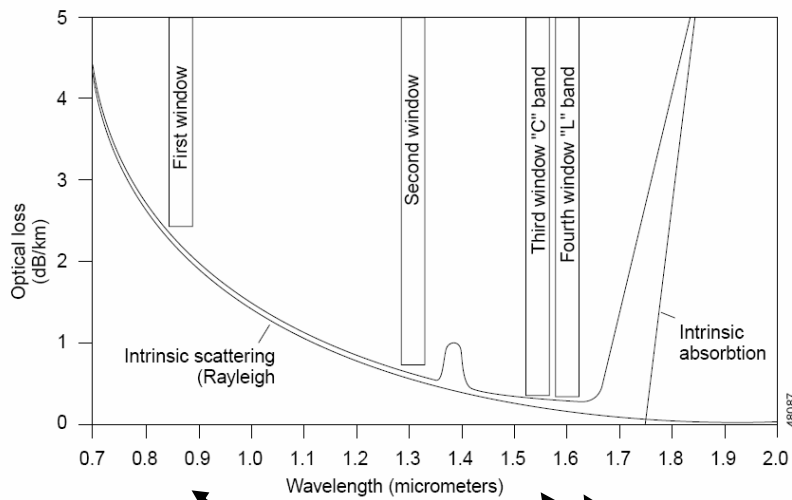
Sites – Intermediate site availability

Financing – IRU (Indefeasible Right of use) or Rental

Availability of Fibre types

SLA – Service Level Agreement

# Tutorial: Linear Fibre Properties



# Fibre Attenuation

Fibre attenuation is basically defined by the fibre impurities

$A = 0,20 \text{ dB/km @ } 1550\text{nm}$

Excess losses that adds to the all over fibre attenuation are

Bend loss, splicing and connector losses

0,05 dB/km excess loss is not rare !

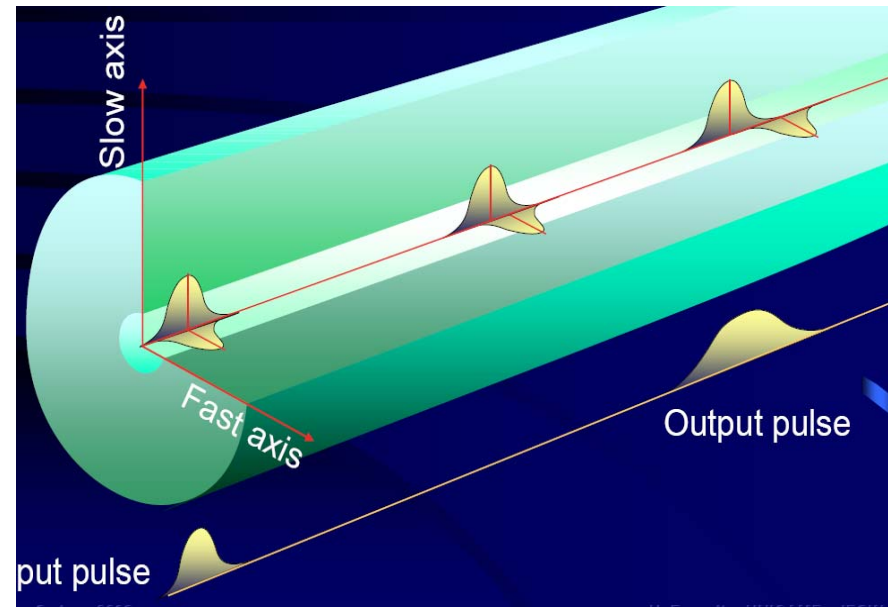
Losses at 0,20 dB/km signifies a newly installed fibre with limited excess loss

Losses at 0,25dB/km signifies an older installation with excess losses

# Fibre PMD

## PMD: Polarisation Mode Dispersion

Stochastic variation of the fibre dispersion with time, temperature and pressure.



The new fibre types have less than  $0,5 \text{ ps}/\sqrt{\text{km}}$ \*

10Gb/s signals tolerate 10ps of PMD which permits 400km fibre  
40Gb/s signals tolerate 2.5ps of PMD which permits 25 km fibre

\* ITU-T G.652

# Fibre Chromatic Dispersion

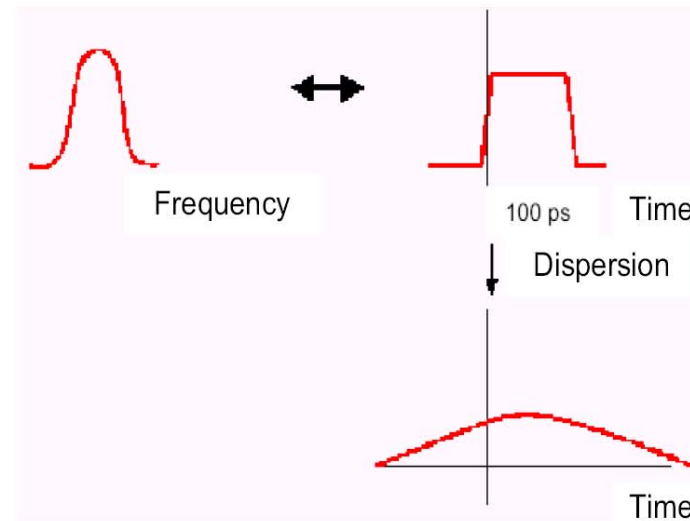
The CMD is a linear effect that can be compensated and cancelled out.

10 Gb/s Signal Has Spectrum Of  
Approximately +/- 10 GHz (0.16) nm.

On SMF Fiber:  
 $17 \text{ ps/nm/km} \times 0.16 = 2.7 \text{ ps/km}$

After 100 km of Fiber  
 $2.7 \text{ ps/km} \times 100 \text{ km} = 270 \text{ ps}$

ps = picosecond



Standard SMF fibre has 17 ps/nm/km of chromatic dispersion  
10-Gb/s receivers can tolerate about 800 ps/nm of dispersion  
500-km systems generates 8500 ps/nm of dispersion

2.5Gb/s transmission is 16 times less sensitive than 10 Gb/s  
2.5Gb/s signals tolerate up to 12,200 ps/nm

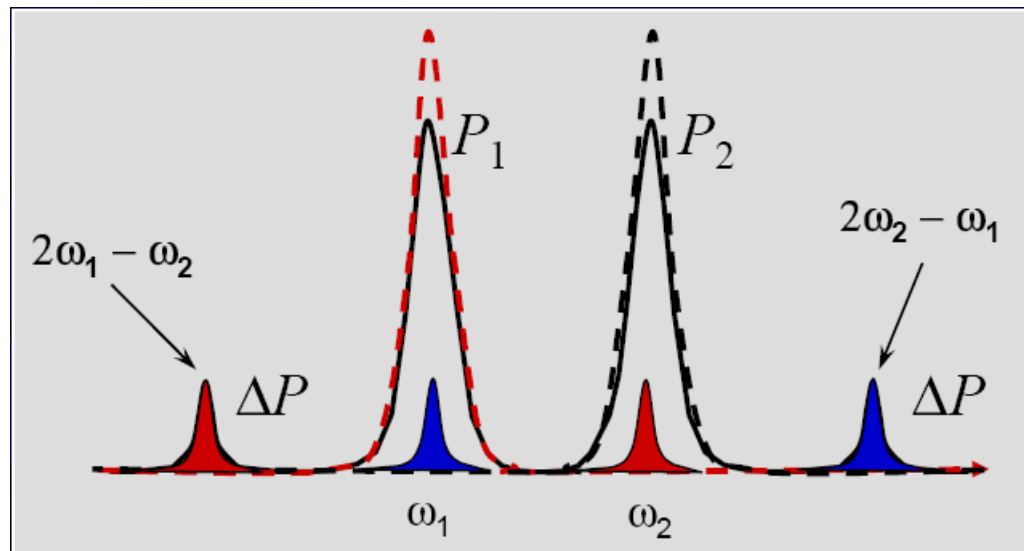
40Gb/s transmission is 16 times more sensitive than 10 Gb/s  
40Gb/s signals tolerate up to 50 ps/nm

# Non-Linearity

## Rule of thumb:

Non-linear effects are present at all time in a fibre system but becomes significant and destructive when the magnitude of optical power launched into a fibre is increased per square unit fibre cross section.

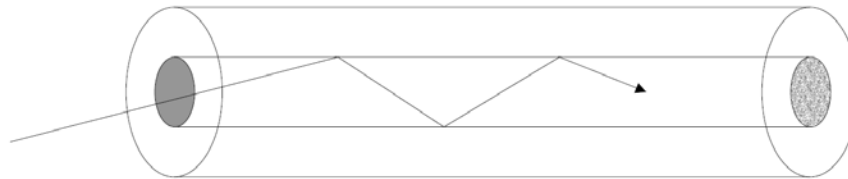
1. FWM limits the channel capacity of a DWDM system.
2. FWM cannot be filtered out
3. FWM is significant for DSF (G.653) which is unsuitable for WDM applications.



# A dark fibre is not “just a fibre” !

**The Dark Fibre is the foundation of your entire network !**

## MM versus SM



### Multi-Mode (MM) - Short Haul Applications

*ITU-T G.651:*

*Multi-Mode optical fibre*

### Single-Mode (SM) - Long Haul Applications

At the time of writing 13 different single mode (SM) optical fibre specifications defined by the ITU-T. These are:

***ITU-T G.652 a, b, c ,d:***

*ITU-T G.653 a, b:*

*ITU-T G.654 a, b, c:*

***ITU-T G.655 a, b, c:***

*ITU-T G.656:*

***Single-mode optical fibre (Standard fibre!)***

*Dispersion-shifted single-mode optical fibre*

*Cut-off shifted single-mode optical fibre*

***Non-zero dispersion-shifted single-mode optical fibre***

*Non-Zero Dispersion for Wideband Optical Transport*



# FYI – Please read later

The G.652a and G.652b specifications define an optical fibre with performance specified at 1310 nm, 1550 nm and 1625 nm but intended for use at, and with a zero chromatic dispersion slope in, the 1310nm region. These optical fibres would be expected to be found in extended length LAN, MAN and access network systems. The more recent variants (G.652.c and G652.d) are not specified at 1625 nm but feature a reduced water peak that allows them to be used in the wavelength region between 1310 nm and 1550 nm supporting Coarse Wavelength Division Multiplexed (CDWM) transmission.

The G.653 specifications define an optical fibre with performance specified at 1310 nm and 1550 nm but with a zero chromatic dispersion slope in the 1550nm region. Such optical fibres were developed to support long-haul single mode transmission systems using erbium-doped fibre amplifiers (EDFA) that only operate in the third window.

The G.654 specifications define an optical fibre with performance specified at 1550 nm only and which only support single mode transmission in that wavelength region.

The G.655 specifications entitled define an optical fibre with performance specified at 1550 nm and 1625 nm but with a non-zero chromatic dispersion slope in these wavelength regions. Such optical fibres were developed to support long-haul systems that use Dense Wavelength Division Multiplexed (DWDM) transmission operating at 1530nm to 1625nm.

The G.656 specification define an optical fibre with performance specified at 1460 nm and 1625 nm but with a non-zero chromatic dispersion slope in these wavelength regions. Such optical fibres were developed to support long-haul systems that use CWDM and DWDM transmission over the specified wavelength range.

# Rough Overview

– *What the fibres are used for !*

ITU-T	TDM @ 1310nm	TDM @ 1550nm	CWDM	DWDM
G.652 SM	Good	OK	OK	OK
G.653 DSF	OK	Good	Bad	Bad
G.654 Loss min.	N/A	Good	N/A	OK
G.655 NZ-DSF	N/A	Good	OK	Good
G.656 W-NZ-DSF	N/A	OK	Good	OK

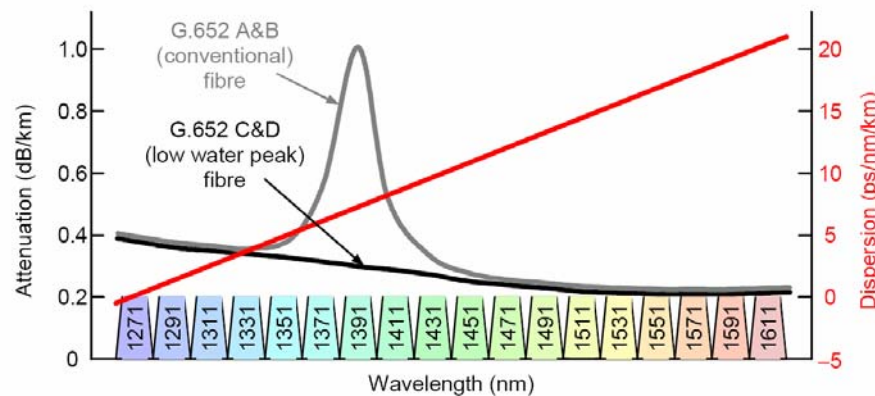
# The important G.652 specification

G.652A:  $A < 0,40$  dB/km @ 1550nm and  $PMD < 0,5$  ps/ $\sqrt{\text{km}}$

G.652B:  $A < 0,35$  dB/km @ 1550nm and  $PMD < 0,2$  ps/ $\sqrt{\text{km}}$

G.652C:  $A < 0,30$  dB/km @ 1550nm and  $PMD < 0,5$  ps/ $\sqrt{\text{km}}$

G.652D:  $A < 0,30$  dB/km @ 1550nm and  $PMD < 0,2$  ps/ $\sqrt{\text{km}}$



Maximum PMD <sub>0</sub> (ps/ $\sqrt{\text{km}}$ )	Link length (km)	Implied Fibre induced maximum DGD (ps)	Channel bit rates
No specification			Up to 2.5 Gbit/s
0.5	400	25.0	10 Gbit/s
	40	19.0 (Note)	10 Gbit/s
	2	7.5	40 Gbit/s
0.20	3000	19.0	10 Gbit/s
	80	7.0	40 Gbit/s
0.10	>4000	12.0	10 Gbit/s
	400	5.0	40 Gbit/s

NOTE – This value applies also for 10 Gigabit Ethernet systems.

# Risk management

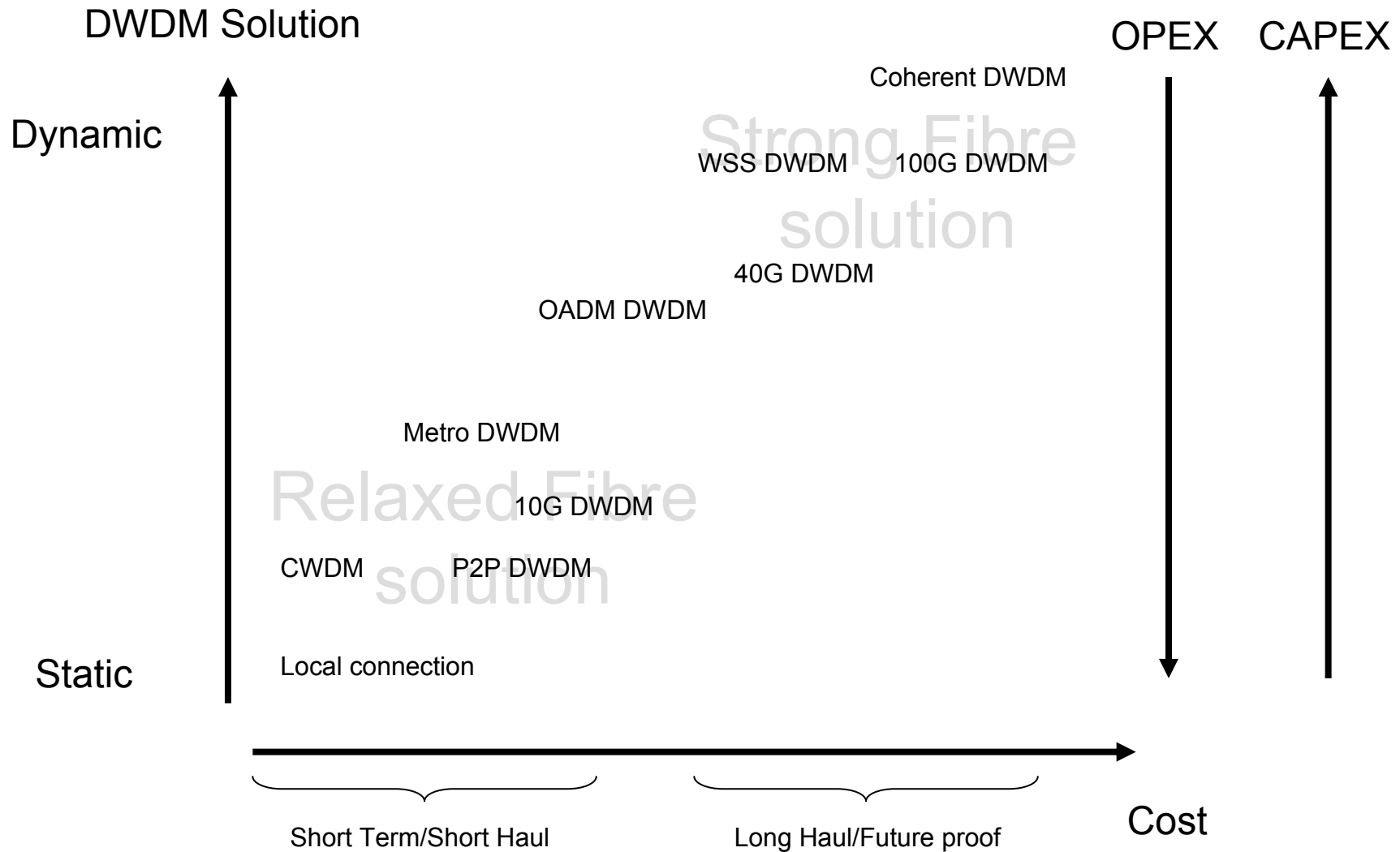
## - SLA of fibre

Standard text in a Service Level Agreement for dark fibre contains options for fibre replacement if the values exceed

**0,25 dB/km attenuation and 0,5 ps/ $\sqrt{\text{km}}$  of PMD**

This could be very damaging to the quality of the network adding high extra costs to the DWDM system.

Take this picture back with you if nothing else 😊



# The 2-3 year history of fibre acquisition in the Nordics

How did it go ?

Any problems ?

Any successes ?

The Fibre “Players” until now:

NORDUnet  
SUNET