Introduction to optical fibre

PIOTR TUROWICZ Poznan Supercomputing and Networking Center

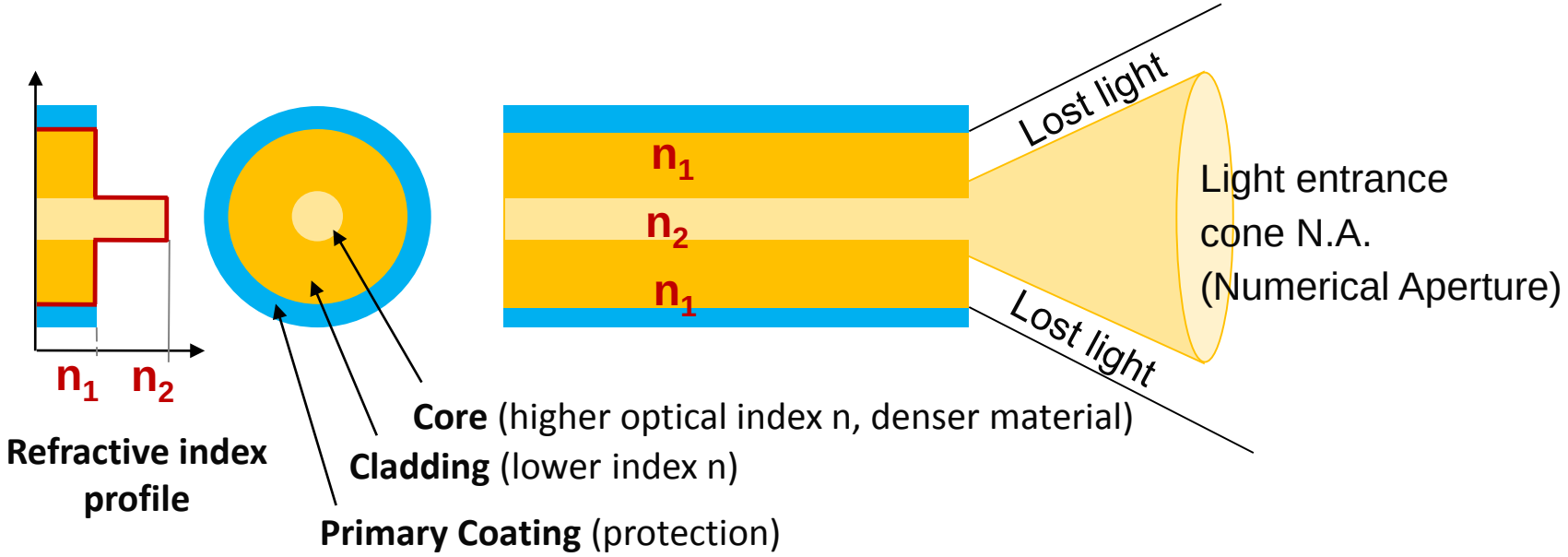
Outline

- Construction and features of optical fibre - principles
- Construction of fibre optic networks
- Fibres and their features in different types of transmission
- Phenomena of CD, PMD, NLE in optical fibre
- Reference to variants of time and frequency signal transfer

Optical fibre

- The basis of the fibre optics:
  - design and operation principle of the optical fibre
- Features of a optical fibre:
  - Attenuation
  - Chromatic Dispersion
  - Polarization Mode Dispersion
  - Non-linear effects

Optical glass fibre structure



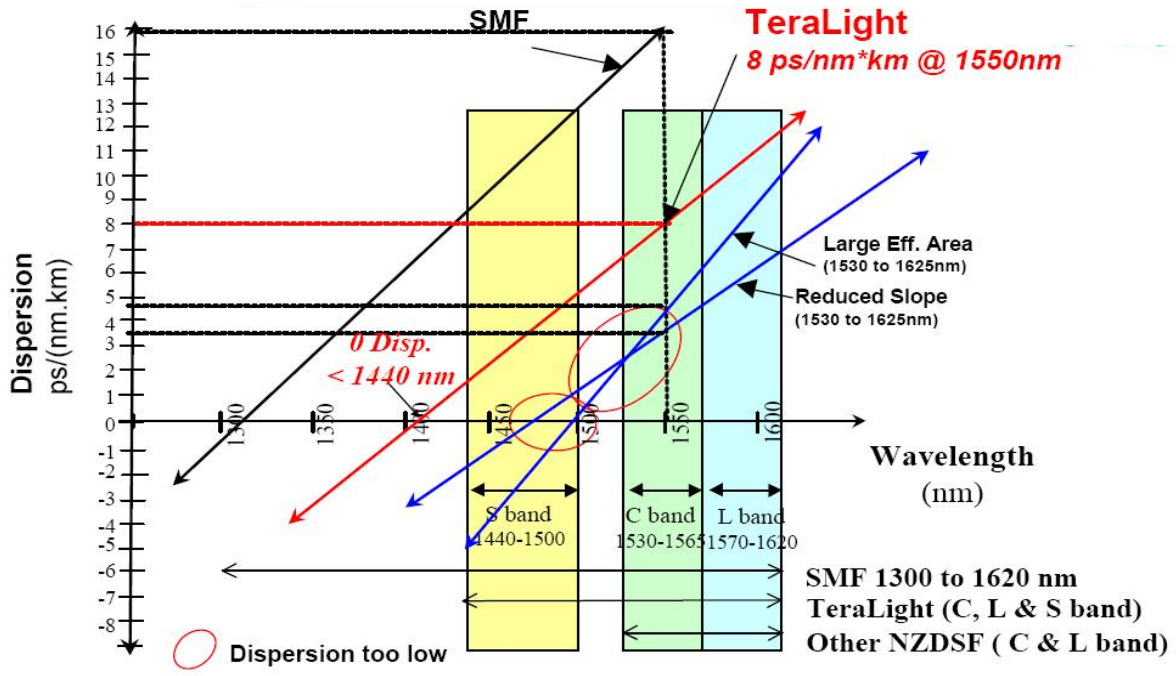
velocity of light in matter always smaller than in vacuum, it is

$$\mathbf{v = C_0 / n}$$

n_{core}= 1.4682

Optical fibre

Chromatic Dispersion – Comparison of optical fibres



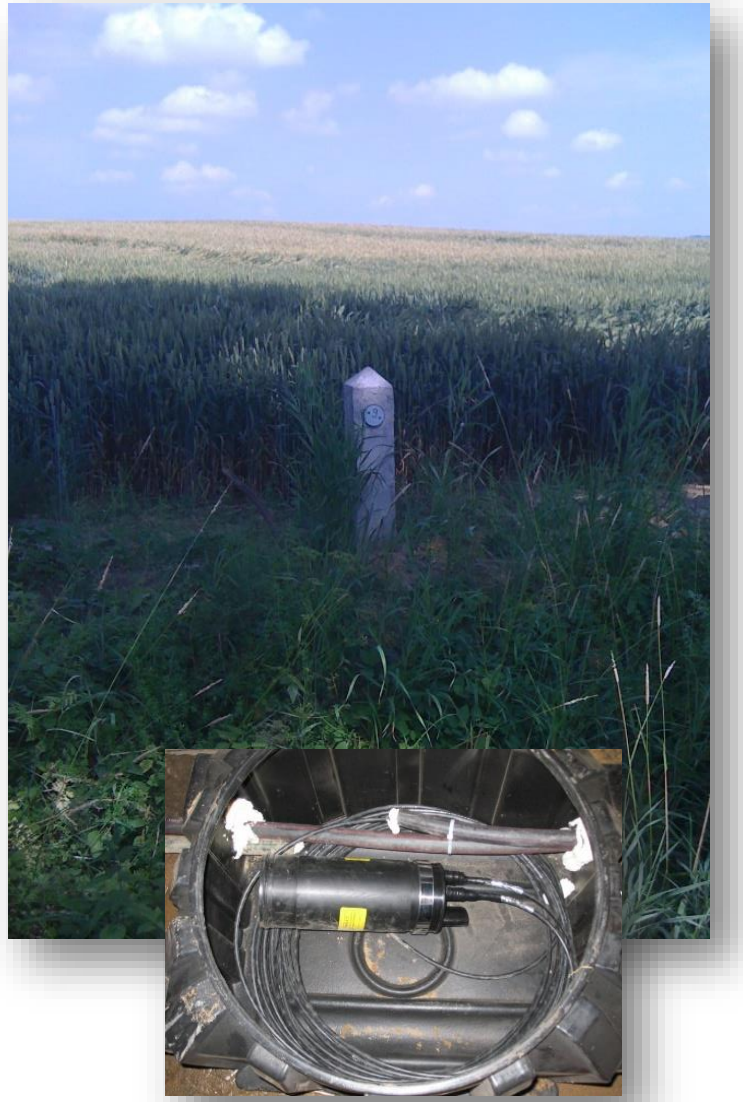
Source: Alcatel presentation

Construction of fibre optic networks

- Buried optical cable
- Buried optical cable nearby railway line
- Aerial optical cable
- Submarine optical cable

Optical networks

- Buried optical cable



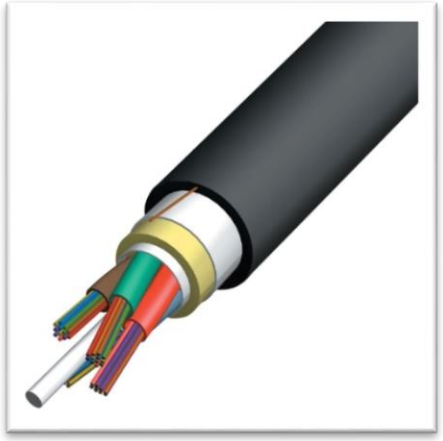
Optical networks

- Buried optical cable next to railway line

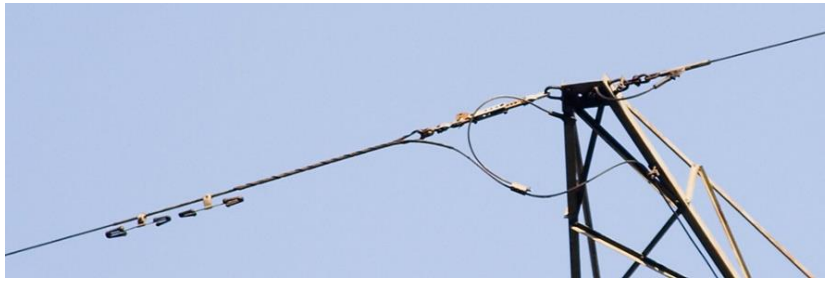
Optical networks

Aerial optical cable

- **ADSS**
  (All-Dielectric Self-Supporting)

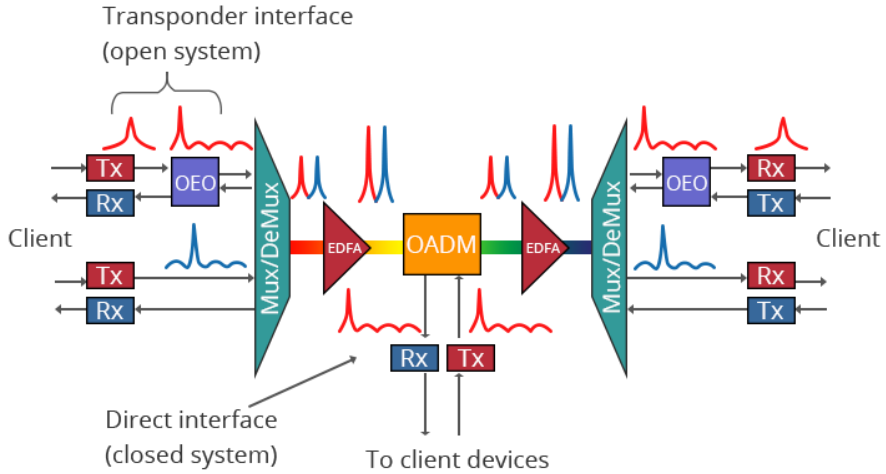


- **OPGW**
  (Optical Ground Wire)



Optical fibre in trasmission systems

- Fibres and their features in different types of transmission
  - Phenomena for signal 10G DWDM systems with long haul multi-channel transmission (DWDM) with amplitude modulation



*) Source: FS.COM April 9, 2015
An Overview of DWDM Technology and DWDM System Components

  - Phenomena for signal 100G in **coherent** DWDM systems

  - Transfer of Time and Frequency signals or optical carrier signals

Phenomena for 10G signal of DWDM

„Old” and „classical” aproach

- Attenuation [dB]
- CD [ps/nm*km]
- PMD [ps/$\sqrt{km}$]

Phenomena for 100G signal of DWDM

„Old” and „New” aproach

- Attenuation [dB]
- PMD [ps/$\sqrt{km}$] -> DGD in real time
  (if changes too fast Rx can lose polarisation lock)
- Interchannel crosstalk
- Non-Linear Effects:

… next

Phenomena for 100+G signal of DWDM

Major Nonlinear Effects:

- SPM - self phase modulation
  predominant in SM and power dependent
- XFM - cross phase modulation
  similar to NEXT but occurring in WDM with adjacent channels
- FWM - Four-Wave Mixing
  intermodulation between three wavelength creating a fourth one (WDM)

- SRS - stimulated Raman scattering

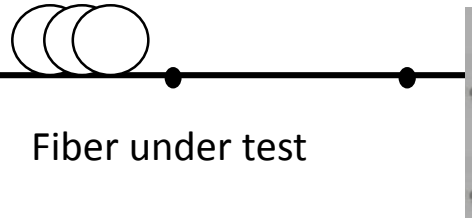
- SRB - stimulated Brillouin scattering

Transmission signals of T&F

- Attenuation [dB]
- CD [ps/nm*km]
- PMD [ps/$\sqrt{km}$]
- NLE (as n_2 changes => changes C_2)
- Temperature change
- Mechanical vibration, other ???

Optical Time Domain Reflectometer

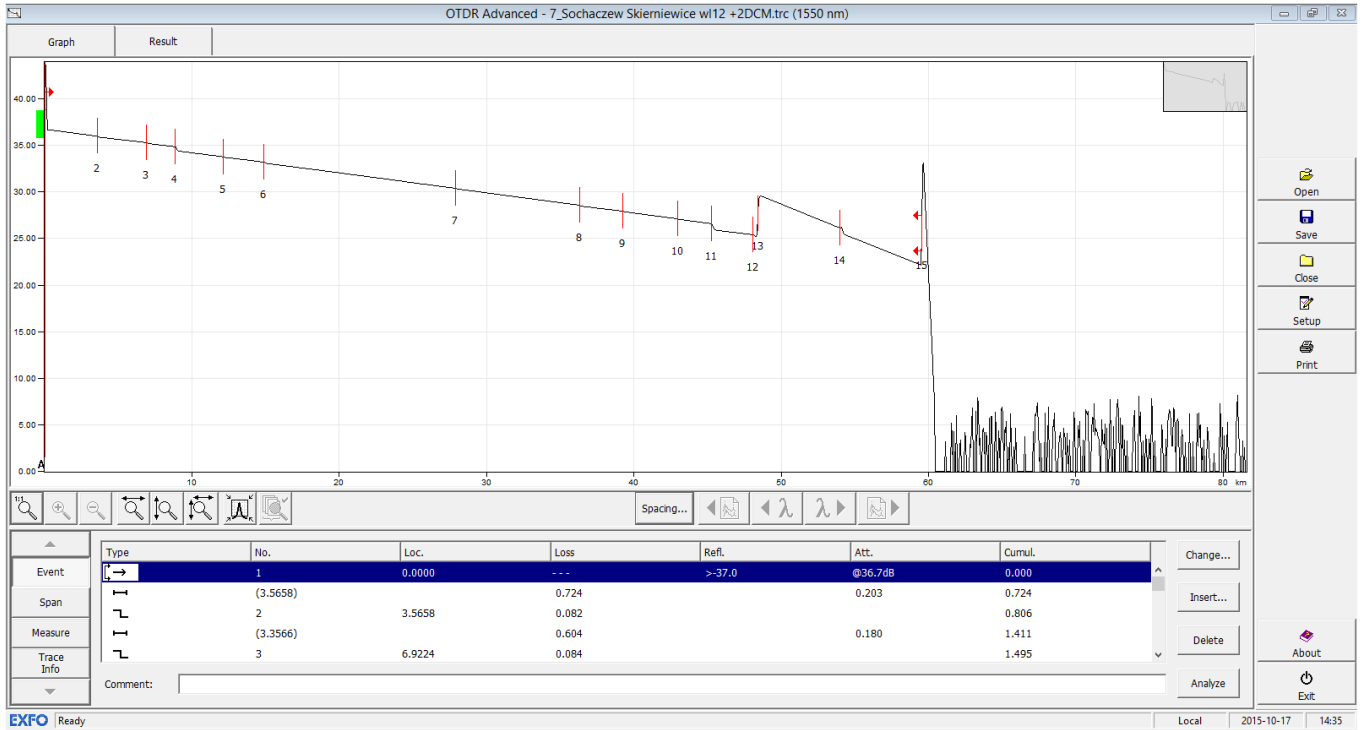
Lauch fiber



Fiber under test

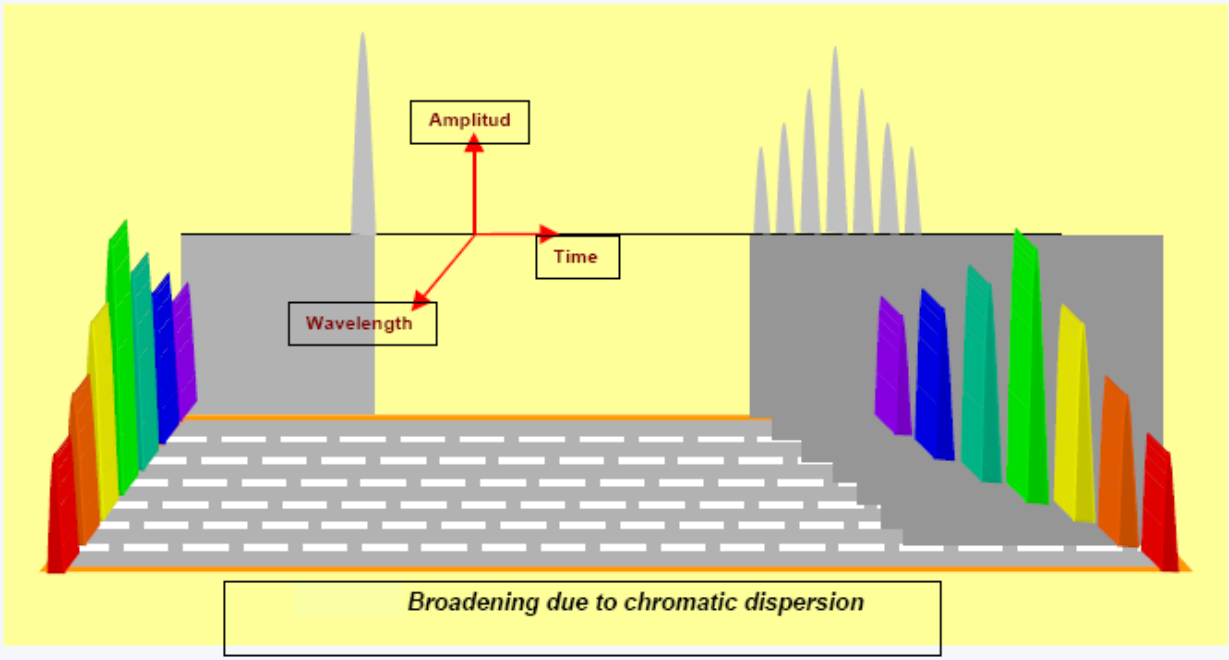
DCM

OTDR
OTDR



Definition of chromatic dispersion

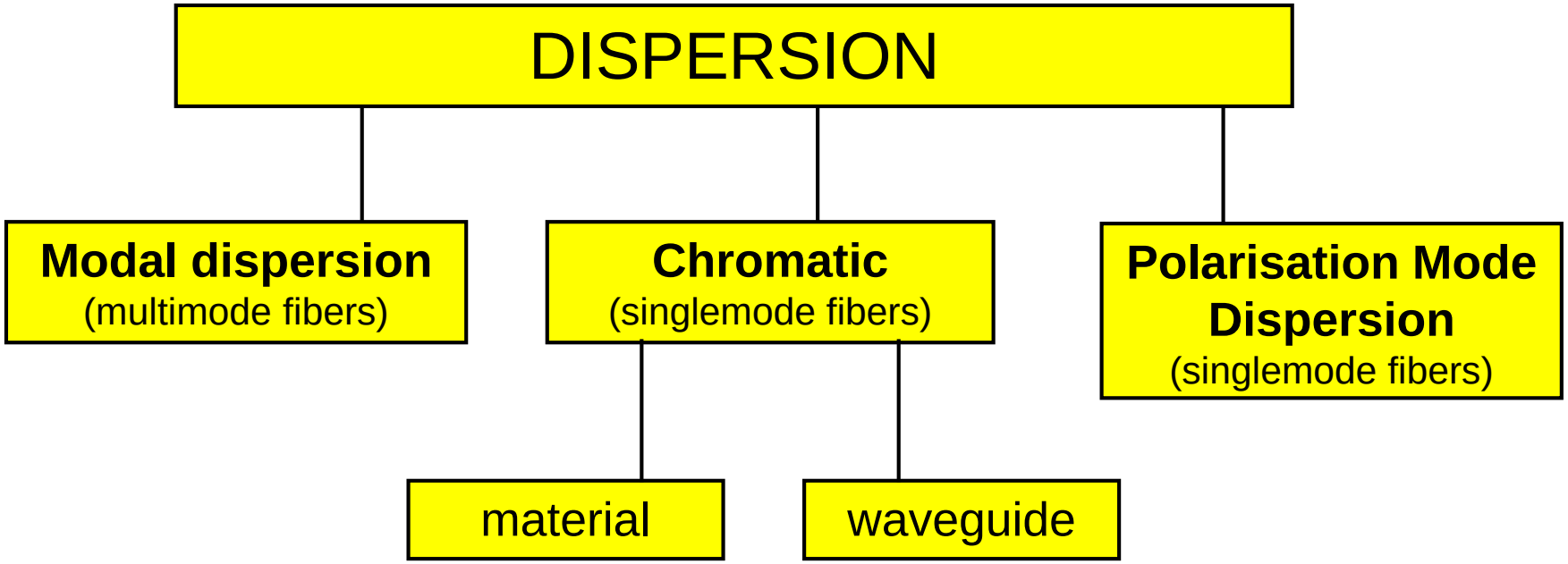
Broadening the optical pulse in the fibre, resulting from a difference of group velocities different waveforms which are the spectral width of the light source.



In a positive dispersion fibre, short (blue) wavelengths arrive before long (red) wavelengths. Because laser light sources are not monochromatic, pulse spreading occurs.

Properties of the optical fibre

Dispersion is the dependence of the parameters of the medium and frequency (wavelength) of a light.



Coefficient of chromatic dispersion

Coefficient of chromatic dispersion is given:

ps/(nm·km)

Changing the light pulse delay for a unit length of the fibre caused by a unit change in the wavelength of the light.

Dispersion is a measure of the duration of the light pulse per unit spectrum after passing of optical fibre unit.

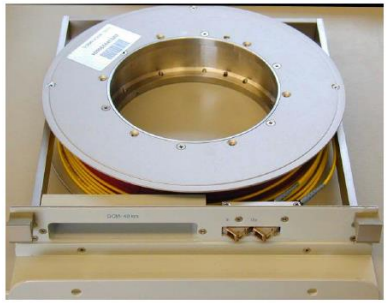
Features of chromatic dispersion

- It is deterministic
- It is linear
- It is unchanged by the environment (instalation conditions, mechanical stress ect.)
- **It could be compensated** 

Compensators of Chromatic Dispersion

DCF module

DCM-P/xx



- Designed for G652 fibers only
- 3 Variants
  - DCM-P/20
  - DCM-P/40
  - DCM-P/80

Variants	Attenuation	Latency	compensated fiber length
DCM-P/20	4,0 dB	25 µs	18 km
DCM-P/40	5,5 dB	50 µs	38 km
DCM-P/80	8,6 dB	100 µs	78 km

Bragg DC module

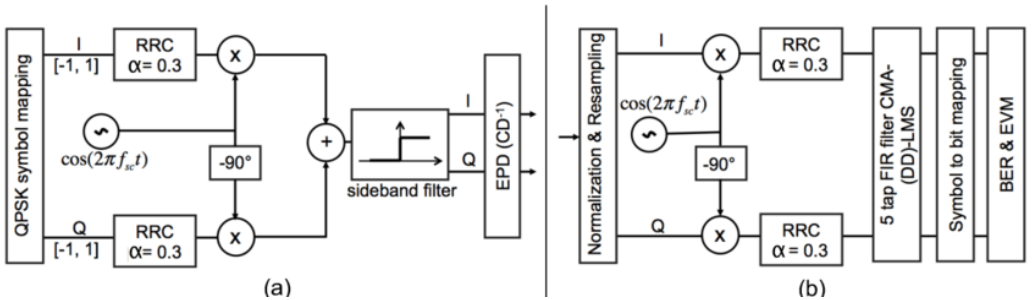
DCG50-M/xxx/SSMF

- Chirped fiber Bragg Grating on 50GHz grid in C-Band
- Compensate SSMF reduced slope fiber
- Latency comparison
  - DCG 60km<0.05µs – 100km<0.05µs
  - DCF 10km<5µs – 100km<50µs
- Maximum per channel input power to the DCM 0dBm
- Not a direct replacement for DCF
- 1 slot width

DCG variants SSMF
- DCG50-M/060/SSMF/50GHz
- DCG50-M/080/SSMF/50GHz
- DCG50-M/100/SSMF/50GHz

XXX	IL	latency
60	4 dB	.05 µs
80	4 dB	.05 µs
100	4 dB	.05 µs

DSP compensation

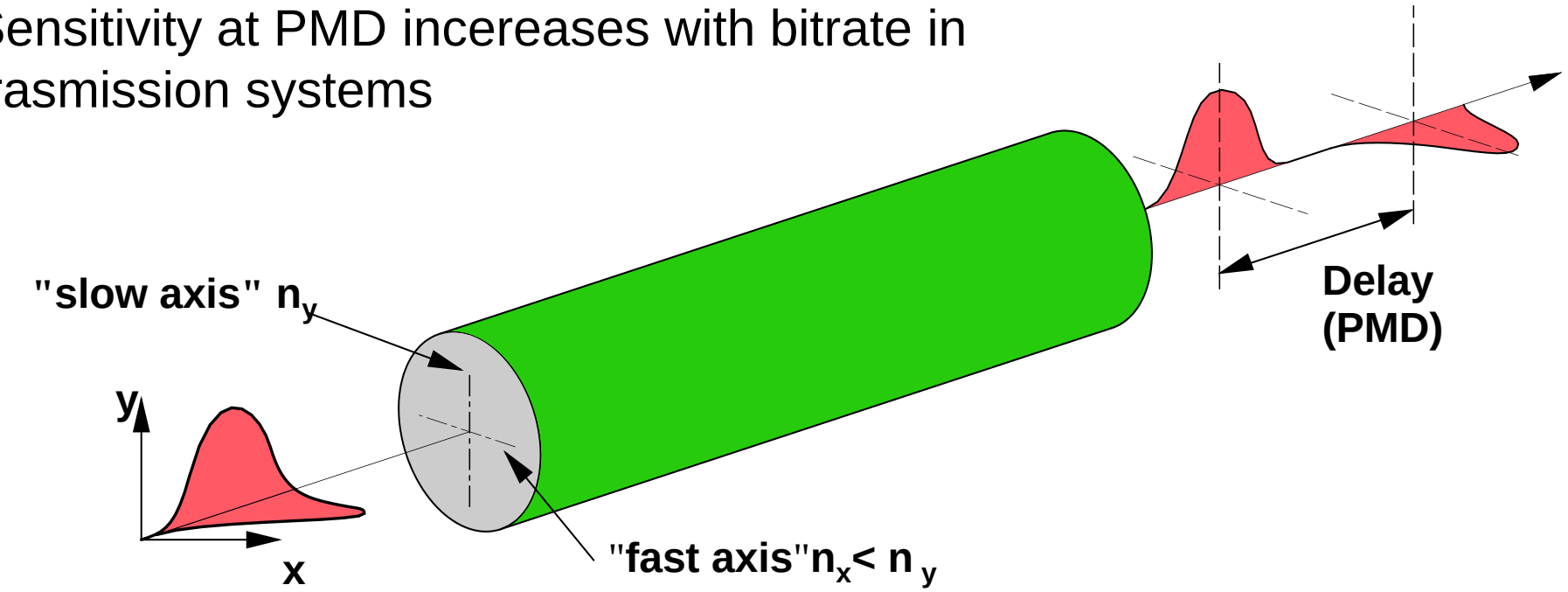


Optical Fiber Technology
Volume 20, Issue 2, P. 158-162

Polarisation Mode Dispersion

PMD occurs in single mode fibers

Sensitivity at PMD incereases with bitrate in trasmission systems

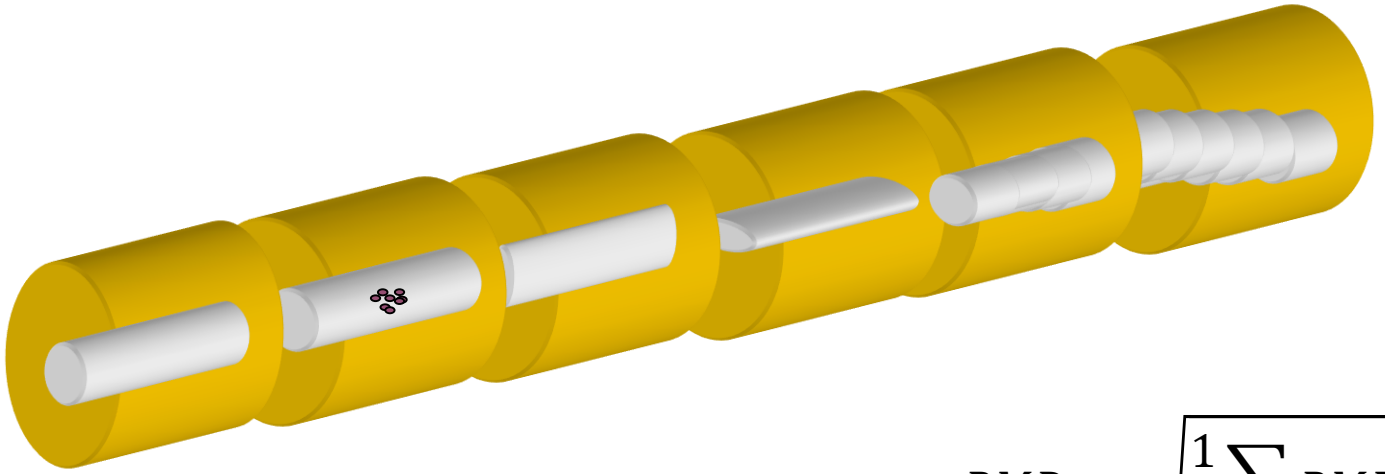


Mod in the SM fiber has two orthogonal polarisations

Polarisation Mode dispersion

Asymmetries in fiber core geometry and/or stress distribution create fiber local birefringence.

A "real" fiber is a randomly distributed addition of these local birefringent portions (concentricity, ageing, vibration, stress, etc.)



$$PMD_T = \sqrt{\frac{1}{n}\sum PMD_i^2}$$

PMD

- only occurs in SM fibers
- It is stochastic
- It is nonlinear
- It is changing (e.g. stressed fiber)
- It can not be compensated (only controlled)

Polarisation Mode dispersion

- PMD is measured in ***[ps]***

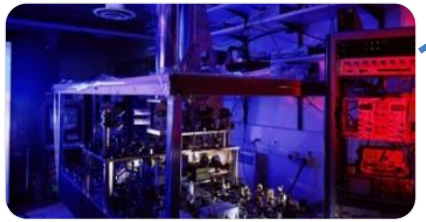
As each new defect in the fibre may partially offset the impact of the earlier defects, but the overall result is a gradual increase in the PMD, so the correct unit for the coefficient which characterizes the fiber is:

- coefficent PMD

$$D = \frac{ps}{\sqrt{km}}$$

Two approaches of T&F signal transfer

Reference Laboratory
- source of T&F signals



Local Module

N x Opt Amp. Bi Dir.

Remote Module

Local Module

Remote Module

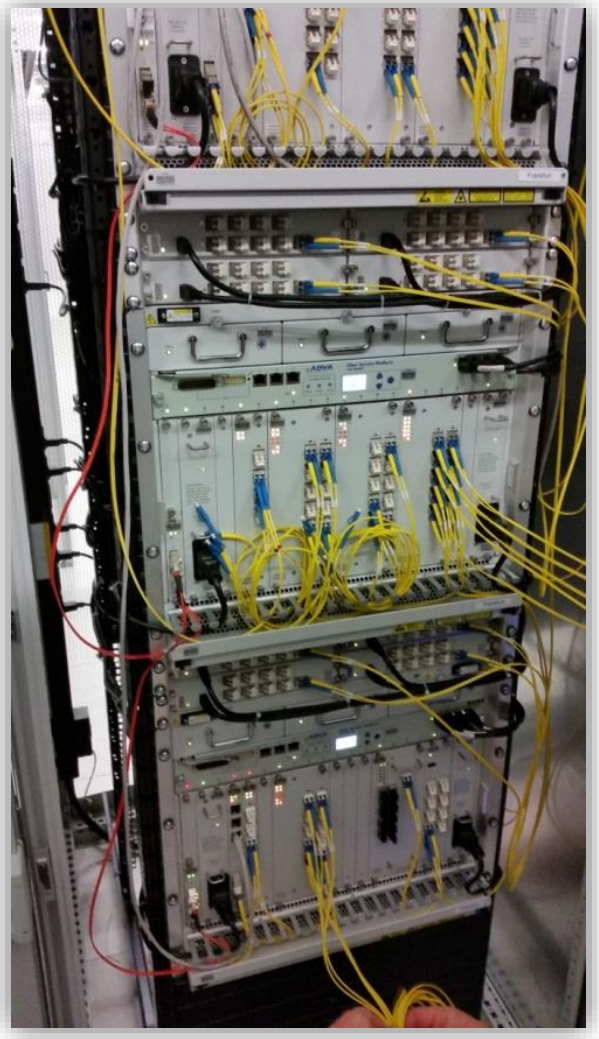
End user

Possible sources of asymmetry of propagation time signals

Individual components of the DWDM system and their colocation

Patchcords and local cabling

Optical lane cable



Summary

- Knowledge of the parameters of the fiber optic line – type of the fibre, attenuation, bi-directional OTDR analysis, CD and PMD measurement
- It's worth knowing how the optical path was built e.g. if the fibres run in aerial cables and if DCM were used in DWDM system
- It is important to know the phenomena in the fibre and their effects on the transmitted signals

Thank you for your attention

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 731107

CLONETS – CLock NETwork Services

Strategy and innovation for clock services over optical-fibre networks

Proposal ID: **731107**
Topic: **INFRAINNOV-2016**
Duration: **30 months**
Start date: **1st January 2017**
Web page: **http://www.clonets.eu**

Coordinator

Participants

Unfunded Partners