Fiber Physical Impairments

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Introduction

- When moving from leased line networks to optical networks, some considerations must be made, to which network one is aiming for.

- Network limitations
- Network capacity (future and existing)
- Overall up-time
- Resilience of network backbone structure

- Taken the given considerations, this leads us to the building blocks of the bare bone network – the fiber.

Network limitations

- Limitations when building an optical network today, has been pushed further and further since the beginning of optical networking, but there are still obstacles.
- We need to transmit more and more capacity, over longer and longer distances which give us the following to consider.

- The distance we want to cover in a single span
- The backscatter and attenuation of that span
  - Which gives us Chromatic Dispersion (CD) to think of
  - And Polarization Mode Dispersion (PMD)

Network capacity

- There are two ways of making large scale networks

- First possibility is to use a lot of fibers
  - Requires a complete fiber backbone with lots of fiber
  - Requires large housing facilities
  - Costly and not efficient
  - Up to 10Gb/s on each fiber pair

- Second possibility is to use only a pair of fibers, and deploy a DWDM system to those fibers
  - Require a pair of fibers (those can be rented)
  - Require 2-3 rack spaces in a housing facility
  - Cost effective
  - Up to 3.2Tb/s (at given time) on a single fiber pair

Overall up-time

- Today, networks must have an up-time of 100%, since even more and more demanding services are running through the network.
- So how is that achieved?
  - Through optical protection switching?
  - Through optical resilience?
  - Through IP protection switching?

- The possibilities can be many, but a good planning for the optical network is also vital via:
  - No crossing optical cables
  - Best performance optical cables
  - Preventative maintenance

Resilience of network backbone structure

- This is the religion of building and maintaining optical networks
- At NORDUnet we prefer to have end-to-end fiber connectivity, which means the fibers must be spliced all the way through from equipment to equipment.
- Other parties want the network to be patched as much as possible.
- Both have their pros and cons which will be explained in full on the following pages.

Resilience of network continued...

- Spliced fiber gives us following

- PRO's
  - The interference from outsiders is minimised.
    - No patch cables to fiddle with or accidentally remove
  - The backscatter, attenuation, an therefore both CMD and PMD is minimised.

- CON's
  - A spliced fiber require a splice team if the fiber breaks at a given point.
    - Potential longer time to fix, than changing a patch cable

Resilience of network continued…

- Patched fiber gives us following

- PRO's
  - Quick change in network routes
  - Easy preventive intervention
    - Can change a route before a planned fiber cut

- CON's
  - Can be accidentally removed
  - More maintenance and cleaning
  - Possible higher attenuation and backscatter
  - Leading to more chromatic dispersion and polarization
- Still needs splicing if the span is cut
- Changing routes may require manual calibration of CD compensation

The importance of quality connectivity

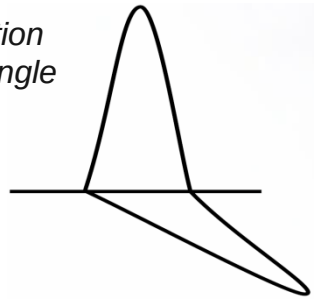
- When using a DWDM system, we always have to think about the dispersion of signals, and how to minimize them.

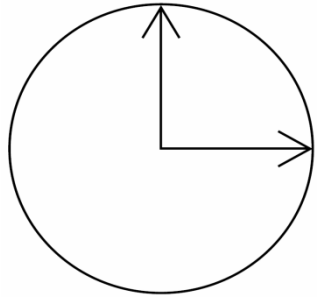
- And why is that?
  - All forms of dispersion degrade a light wave signal, reducing the data carrying capacity through pulse-broadening.
  - Chromatic dispersion results from a variation in propagation delay with wavelength, and is affected by fiber materials and dimensions.
  - At 10 Gb/s, a delay (PMD) as low as 10 picoseconds causes a significant increase in BER. Your system may function well and transmit clear communications at 2.5 Gb/s.
    - Imagine moving for 40 Gb/s and beyond then?

PMD short

- Individual pulses in a fiber are made of two perpendicular signals like shown on the pictures

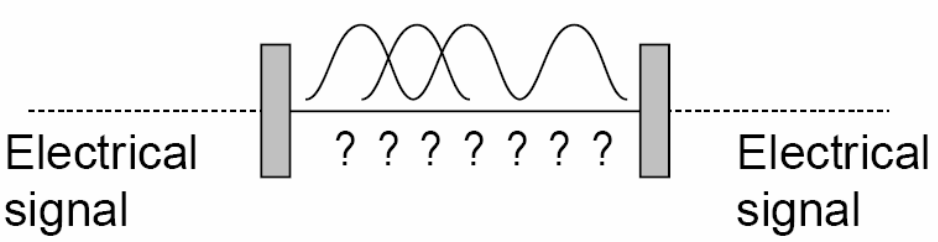
The polarization states of a single pulse





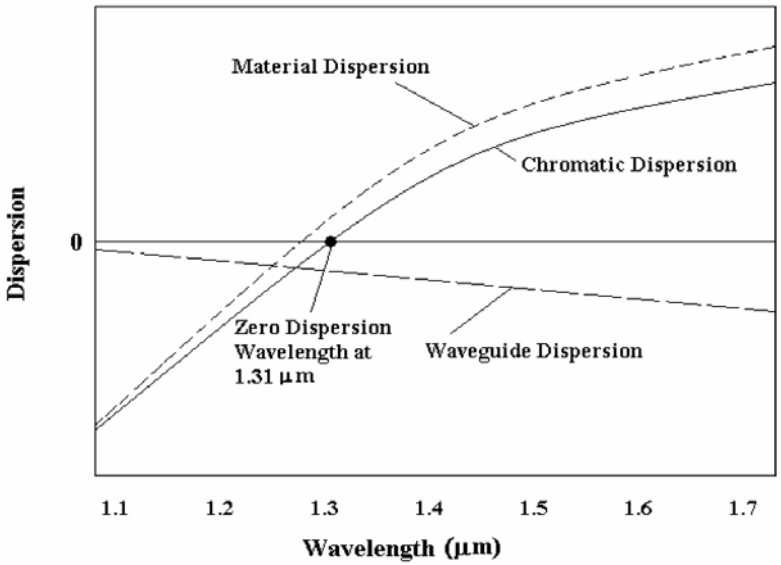
Propagation of polarization states in a fiber

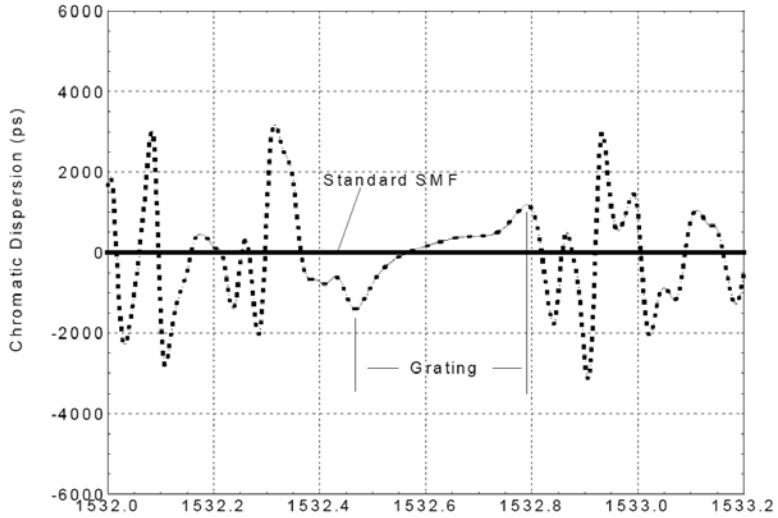
- If the signals are delayed by irregularities in the fiber, the resulting pulse will be a broadened pulse that will overlap the succeed signal.



CD short

- Chromatic dispersion is a broadening of the input signal as it travels down the length of the fiber. This concept could be considered optical phase. It is important to mention optical phase before any explanations of CD or group delay because of their mathematical relationship.
- Chromatic dispersion is the second derivative of optical phase with respect to optical frequency.





Going for full connectivity

- At NORDUnet we believe that having the best network performance and quality, comes from minimizing the X factors.
  - Outside influence
  - Different cable types
  - Patch cables
  - Connections
  - Attenuation
  - Chromatic dispersion
  - Polarization

Full connectivity continued…

- NORDUnet is moving towards a fully spliced optical network
  - Considering the presence of polarization, this is believed to give the best quality.

- How is this obtained?
  - Splicing the network end-to-end
  - Using a minimum of patch cables
    - Less cleaning and error posibilities

Connector and Splice Loss 1

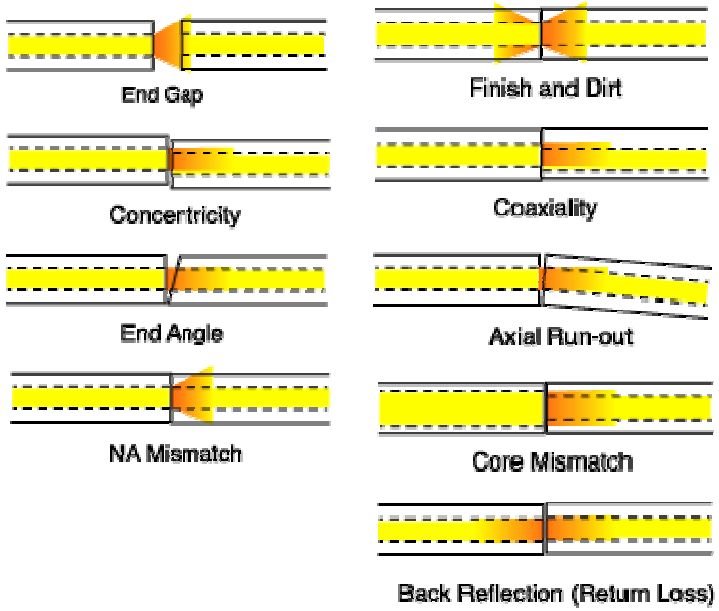
- Connector and splice loss is caused by a number of factors.
  - Loss is minimized when the two fiber cores are identical and perfectly aligned, the connectors or splices are properly finished and no dirt is present.

- End gaps cause two problems, insertion loss and return loss.
  - The air gap between the fibers causes a reflection when the light encounters the change “n” refractive index from the glass fiber to the air in the gap. This reflection (called fresnel reflection) amounts to about 5% in typical flat polished connectors.
    - This means that connectors with an air gap cannot have less than 0.3 dB loss.
    - This reflection is also called back reflection or optical return loss, which can be a problem in laser based systems.

Connector and Splice Loss 2

- Connectors use a number of polishing techniques to insure physical contact of the fiber ends to minimize back reflection.

- Mechanical splices, can reduce back reflection by using non-perpendicular cleaves, which cause back reflections to be absorbed in the cladding of the fiber.



Different ways to generate attenuation, while merging two fibers together

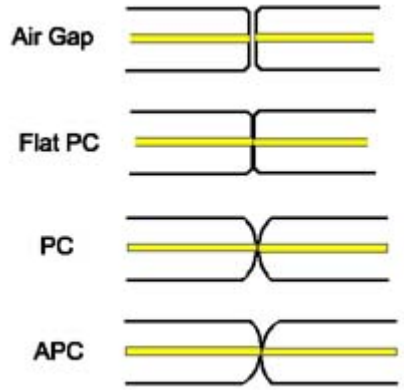
Connectors types and use

- EIA/TIA 568 B allows any fiber optic connector as long as it has a FOCIS (Fiber Optic Connector Intermateability Standard) document behind it.
  - We have the "Small Form Factor" (SFF) connectors, including LC, MU and the E2000 in the equipment used in today's DWDM systems.

- Fiber optic connectors can have several different ferrule shapes or finishes, usually referred to as polishes.

LC/APC connector

SC/APC and UPC connector

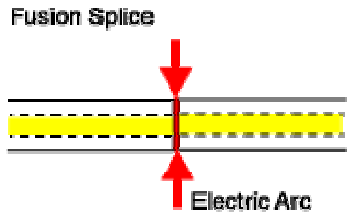


The APC (Angled Polished Connector), reflects light at an angle that is absorbed in the cladding of the fiber.

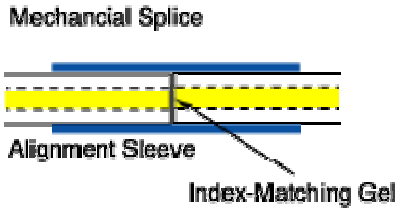
Splices

- Splices are "permanent" connections between two fibers.
  - There are two types of splices, fusion and mechanical.

- Fusion splices are made by "welding" the two fibers together usually by an electric arc.
  - Good fusion splicer's cost from €11,000 to €29,000.
  - Fusion splices give very low back reflections and are preferred for single mode high speed capacity.



All fibers in NORDUnet backbone is fusion spliced.

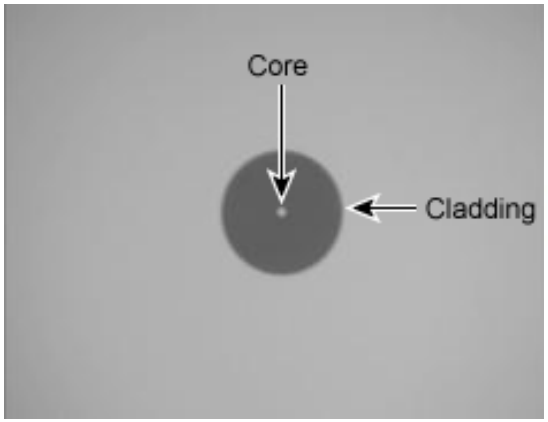


Cleaning of connectors

- A rough surface will scatter light and dirt can scatter and absorb light.
  - Since the optical fiber is so small, typical airborne dirt can be a major source of loss.
  - Whenever connectors are not terminated, they should be covered to protect the end of the ferrule from dirt.
  - One should never touch the end of the ferrule, since the oils on one's skin causes the fiber to attract dirt.
  - Before connection and testing, a must is to clean connectors with lint-free wipes, or even better a reel cleaner.

Cleaning continued…

- When cleaning connectors, it is vital that both the connector on the patch cable and the connector on the ODF are cleaned.
  - For static ODF's where it is not possible to access the backside connector, a stick can be used.
  - A fiber microscope must be used to verify the connectors surface for dust and scratches.
- ❗ Cleaning is NOT using a T-shirt



Optical measuring equipment

- The network have to be tested, both for quality and for linearity.
- This work is normally carried out by the supplier of the rented dark fiber, or any subcontractor.
  - It's preferred to have a third party measuring the fiber span in the entire network, as they will have a neutral approach to the results.
- Mandatory fiber measurements when aiming for DWDM networks is as follows:
  - OTDR – Optical Time Domain Reflectometer
  - PMD – Polarization Mode Dispersion
  - CD – Chromatic Dispersion

Questions

- Questions welcome

Thank you!