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Chromatic dispersion

.

Information Society and Media

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What is dispersion?

Dispersion is the time domain spreading or broadening of the transmission signal light pulses - as they travel through the fibre

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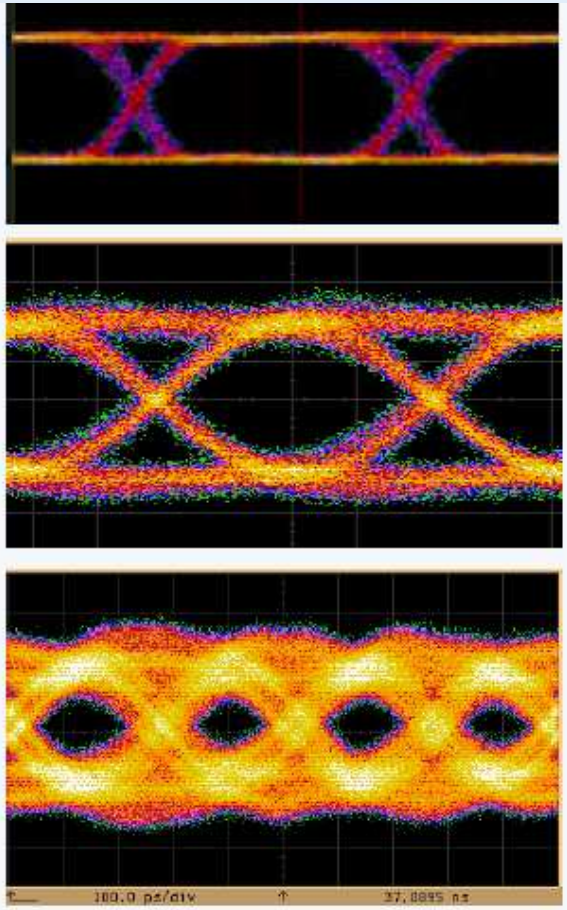
Effects of dispersion

If you send an optical pulse in a fiber, its shape will change



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Overview

- The optical pulse is made of more than one component (wavelength/polarisation state)
- Each component travels at slightly different speeds
- Therefore the different components will arrive at different times
- ***The Difference in arrival time at receiver is the differential delay***

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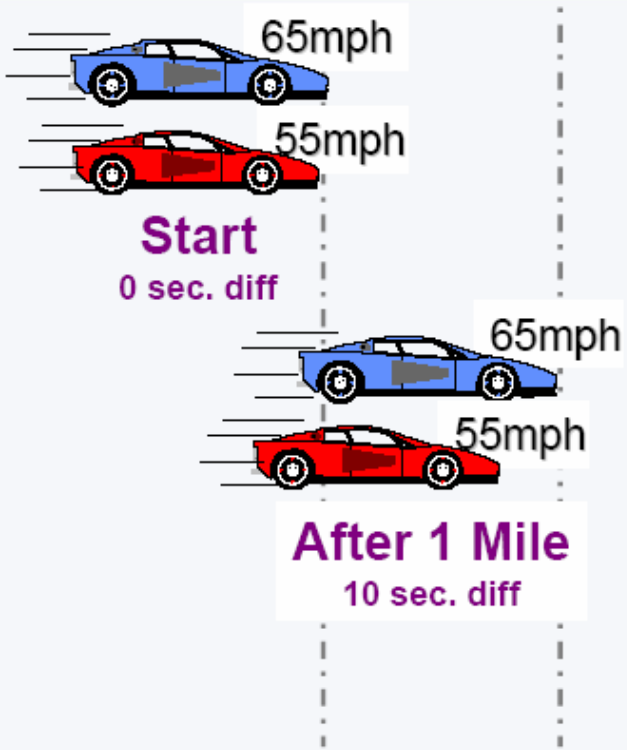
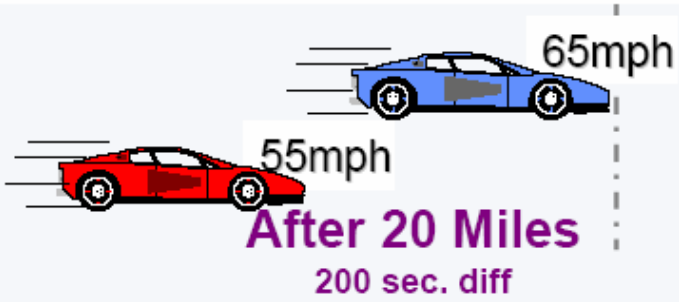
Differential delay



The difference in *speed* between the two cars (or two components of light) causes them to arrive at the end at different times.

The longer the distance - the more time difference between them.



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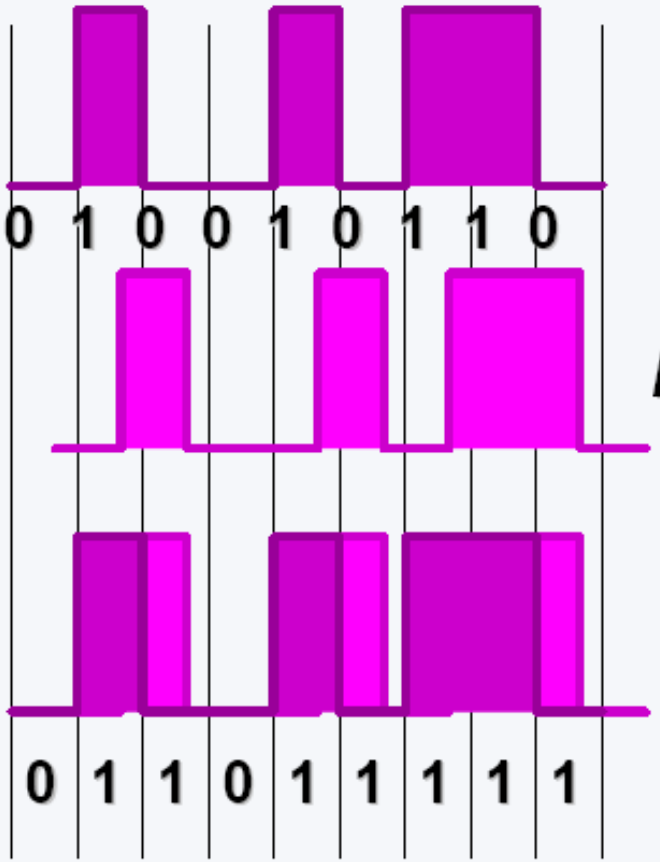
Increased Bit Error Rate



Original Signal

+

Differential Delay

↓

Bit Errors

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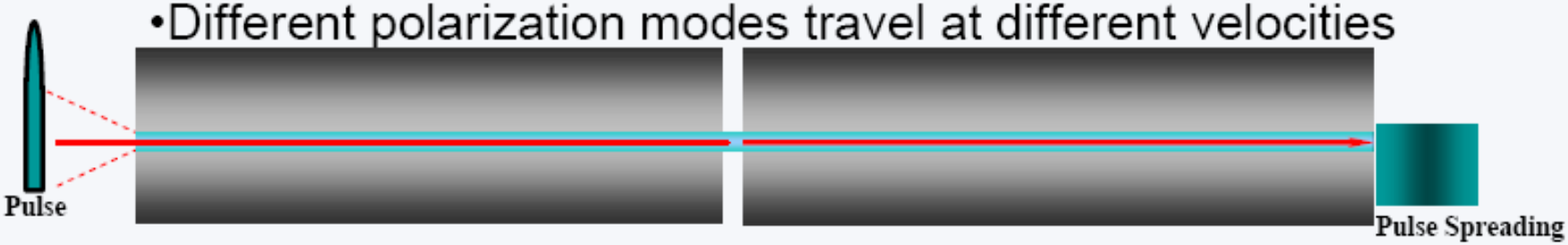
Types of dispersion

- **Chromatic Dispersion**:
  - Different wavelengths travel at different velocities

- **Polarization mode dispersion**:
  - Different polarization modes travel at different velocities



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Types of dispersion

- **Chromatic Dispersion**:
  - Is deterministic
  - Is linear
  - Is not affected by environment
  - Can be compensated
- **Polarization mode dispersion**:
  - Is stochastic
  - Is not linear
  - Is affected by the environment
  - Cannot be easily compensated

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Chromatic Dispersion Definition

All light sources used for optical fibre transmission emit light, not at a single wavelength λ, but in a band of spectral width $\Delta\lambda$, distributed around λ

The speed at which light travels through a fibre depends on its wavelength and on the design of the fibre

Thus some wavelengths of the band of which the pulse is comprised may be delayed compared with others, leading to pulse spreading with time after traversing a significant length of fibre

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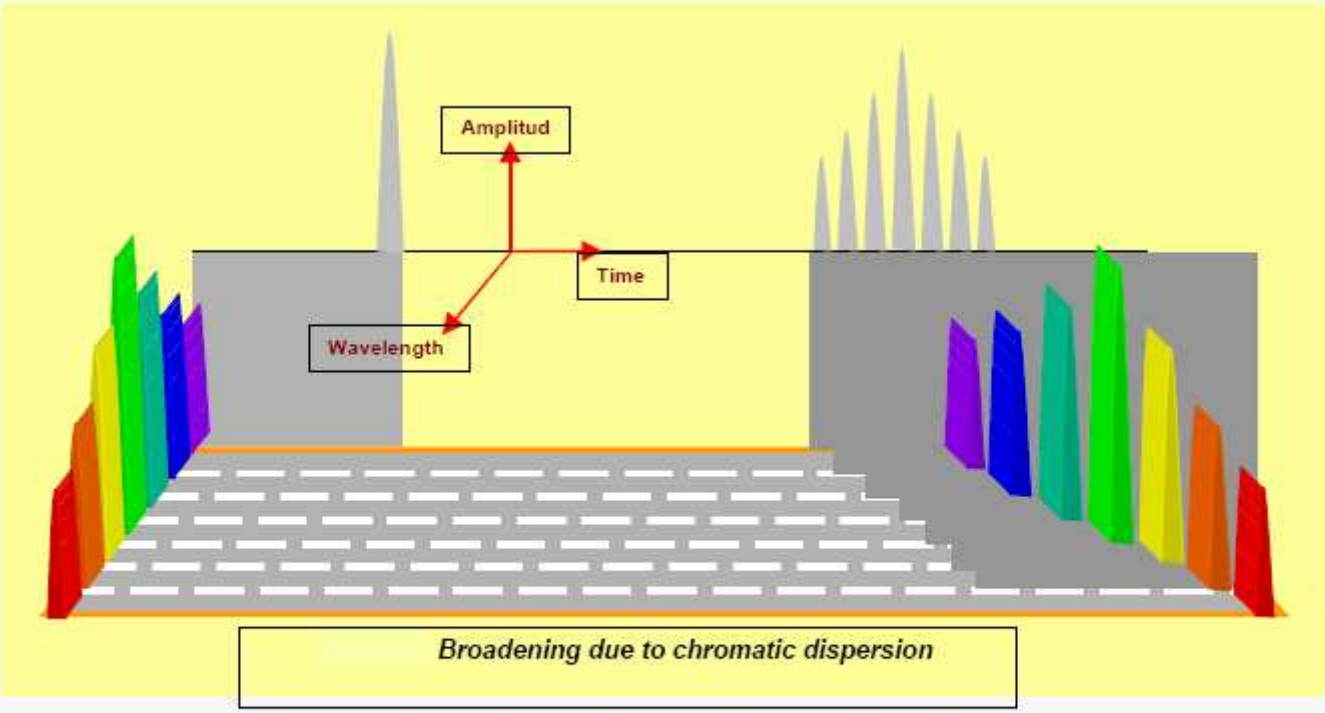
Chromatic Dispersion Definition



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

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The cause of Chromatic Dispersion

Two effects contribute to the total Chromatic Dispersion in fibre:

- Material Dispersion
- Waveguide Dispersion

Material Dispersion depends on the materials in-built Refractive Index and we are unable to change this.

Waveguide dispersion depends on the fibre's refractive index profile and its this part that can be engineered to allow manufacture of speciality fibres with specific dispersion profiles

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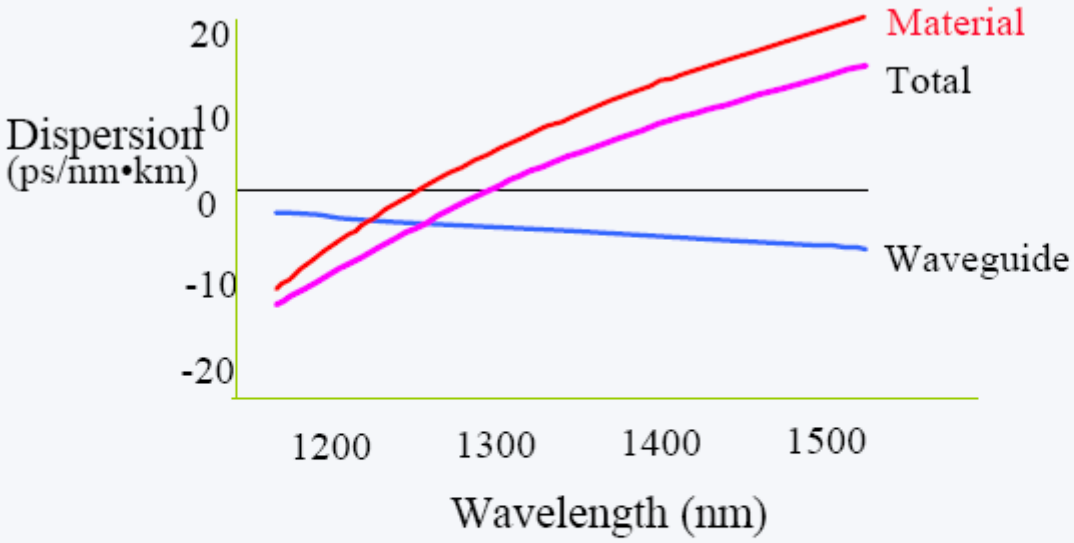
Dispersion by design



By changing the Waveguide dispersion (i.e., altering the fibre design) and balancing it against the Material dispersion (fixed), the dispersion characteristics of the fibre can be engineered to required values over the preferred operating window

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Fibers type

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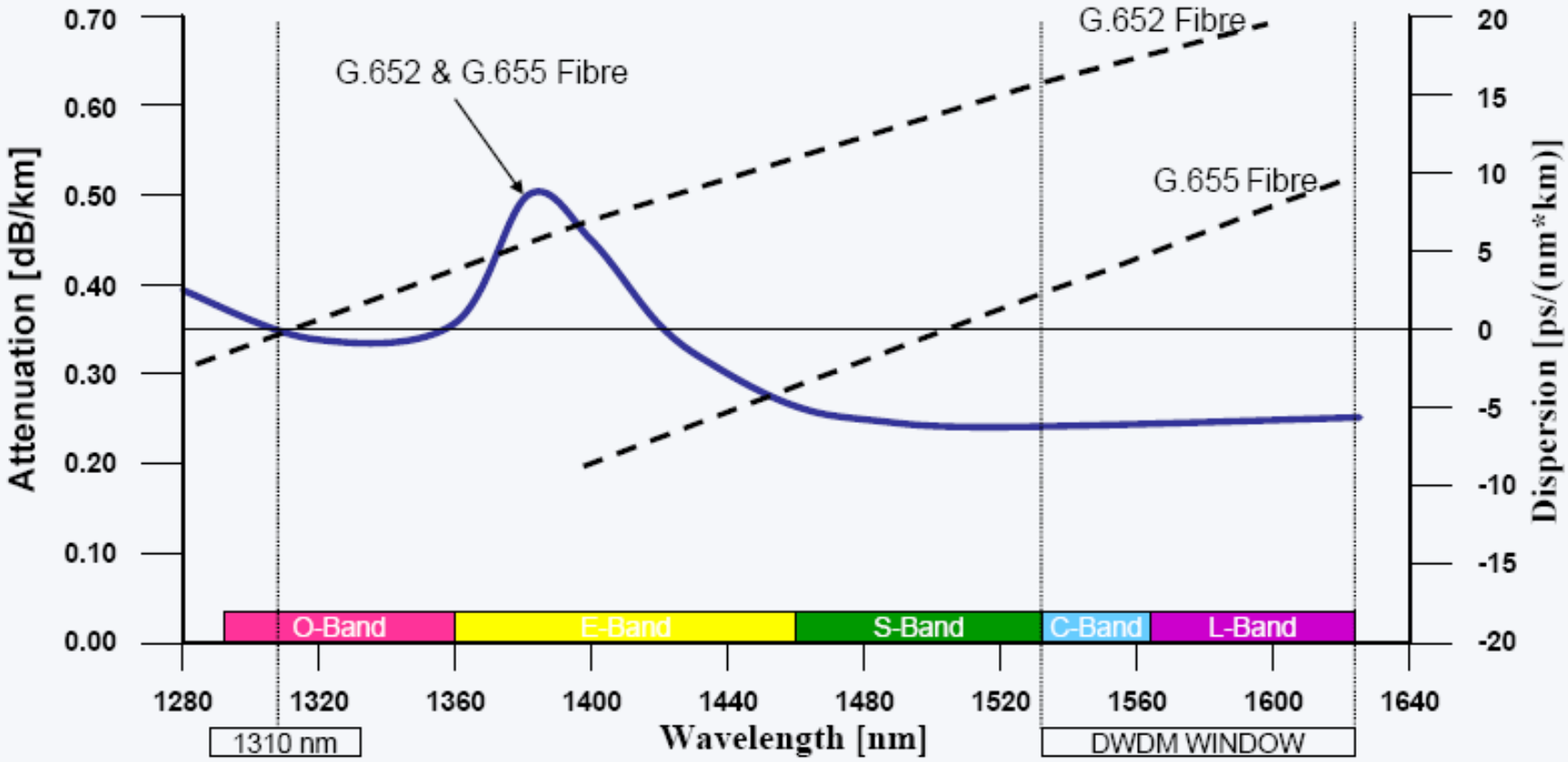
Optical Fibers: Attenuation & Dispersion



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Why is measuring Dispersion so important?

As transmission speeds go up, the residual dispersion allowable at the receiver to give a fixed system penalty goes down.

Receiver Tolerance for a 1dB power penalty

2.5 Gb/s	16,000ps/nm
10 Gb/s	1,000ps/nm
40 Gb/s	60ps/nm

e.g. An 80km link at 1550nm will build up 17ps/(nm.km) x 80km = 1360ps/nm. Therefore at data rates at 10Gb/s and higher it is necessary to compensate for the chromatic dispersion.

To compensate effectively you need to measure the dispersion of the link.

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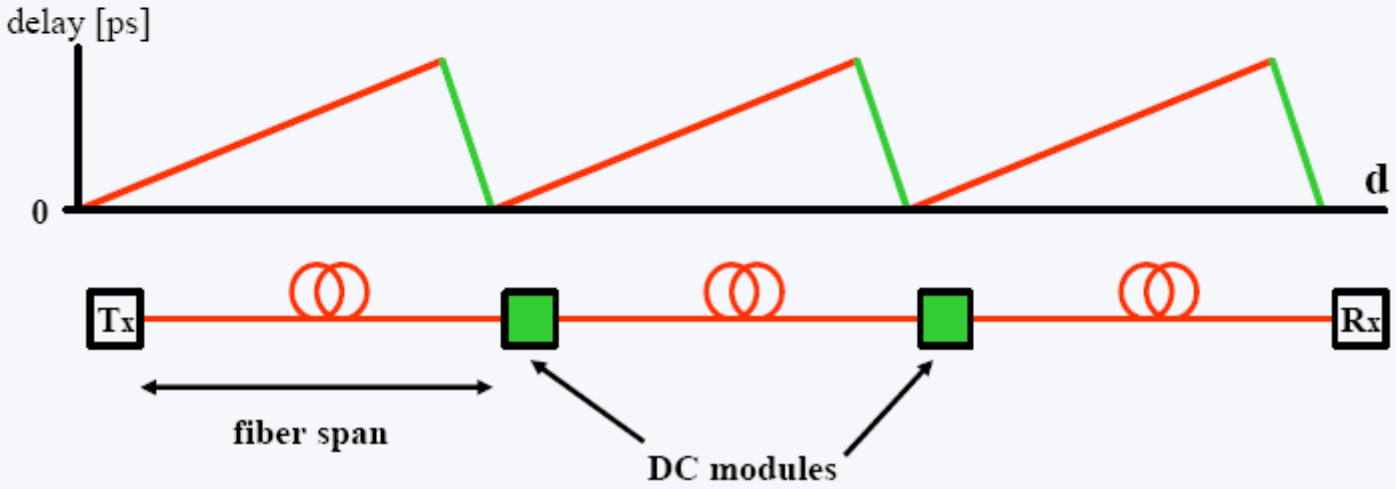
Dispersion compensation

Good News : CD is stable, predictable, and controllable.

Dispersion compensating fiber ("DC fiber") has large negative dispersion -85ps/(nm.km)

DC fiber modules correct for chromatic dispersion in the link



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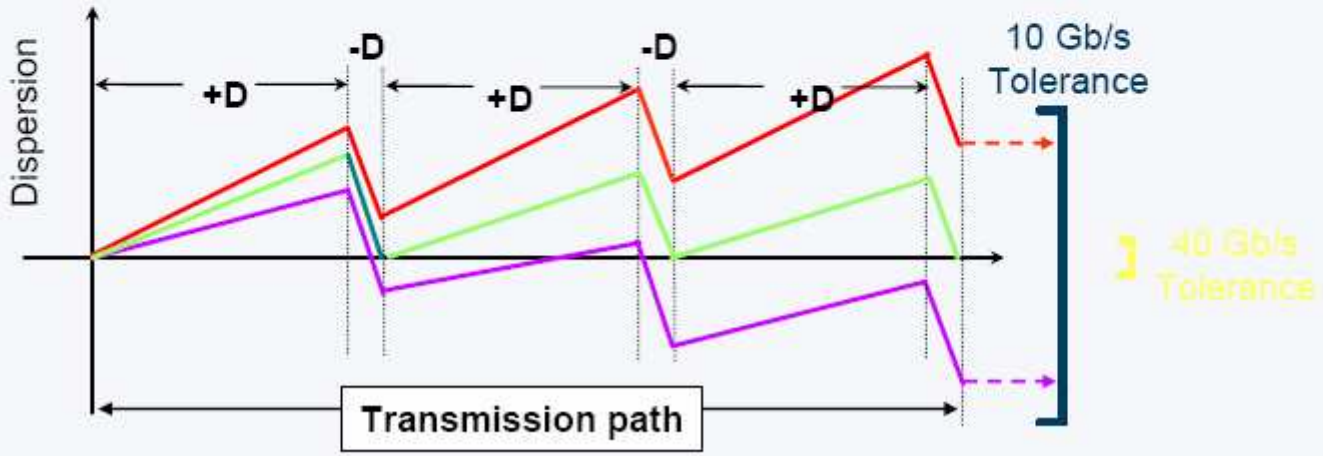
Dispersion compensation for DWDM

Dispersion compensation modules only compensate exactly for centre channel of the band of wavelengths. The other DWDM Channels will be left with residual dispersion.

DWDM system design requires knowledge of end-to-end CD as a function of wavelength… especially for long-haul



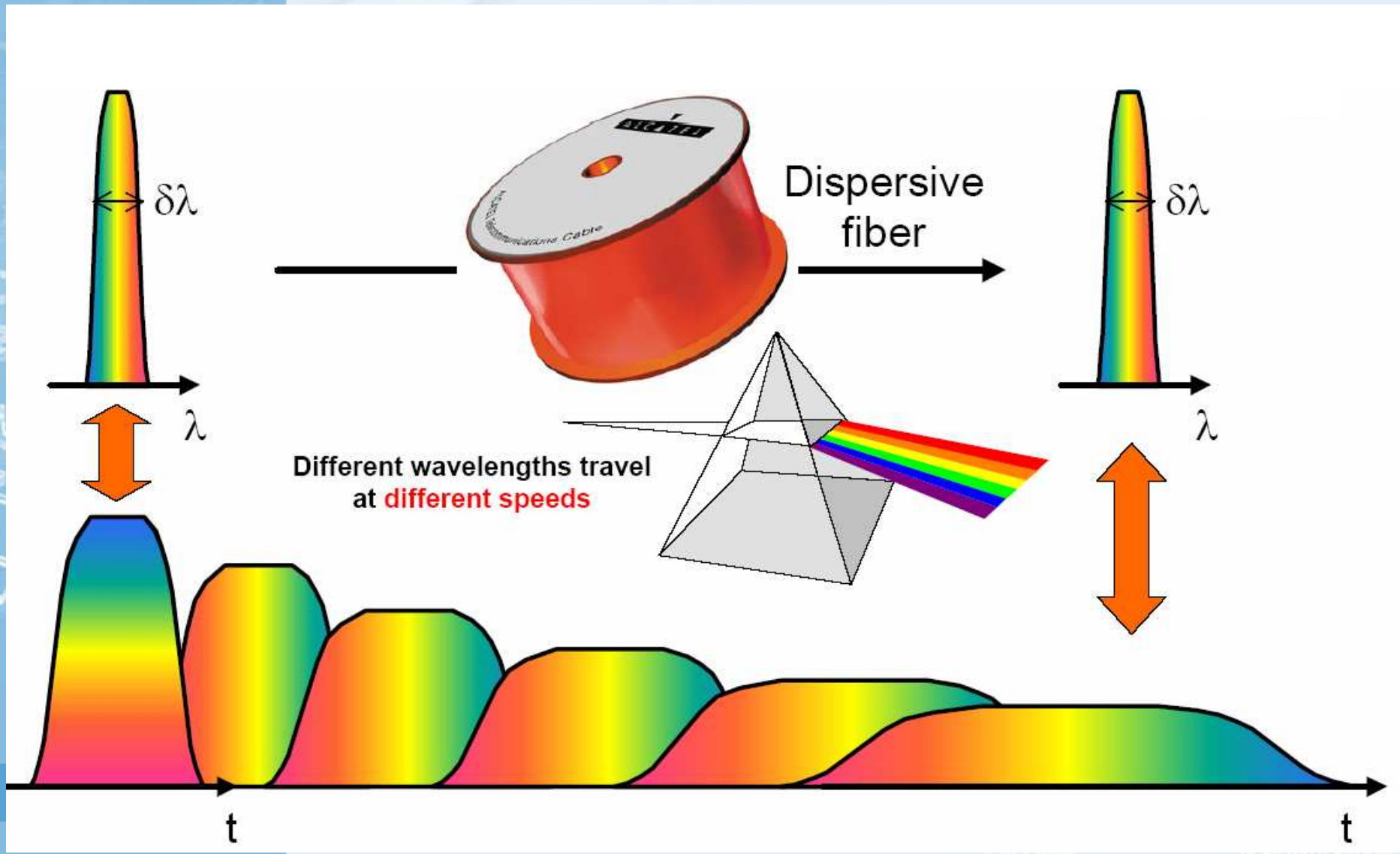
CD management

***Prevention*:**

1. Compensation:
   - Fibers DCF & RDF,
   - Bragg Gratings technique.

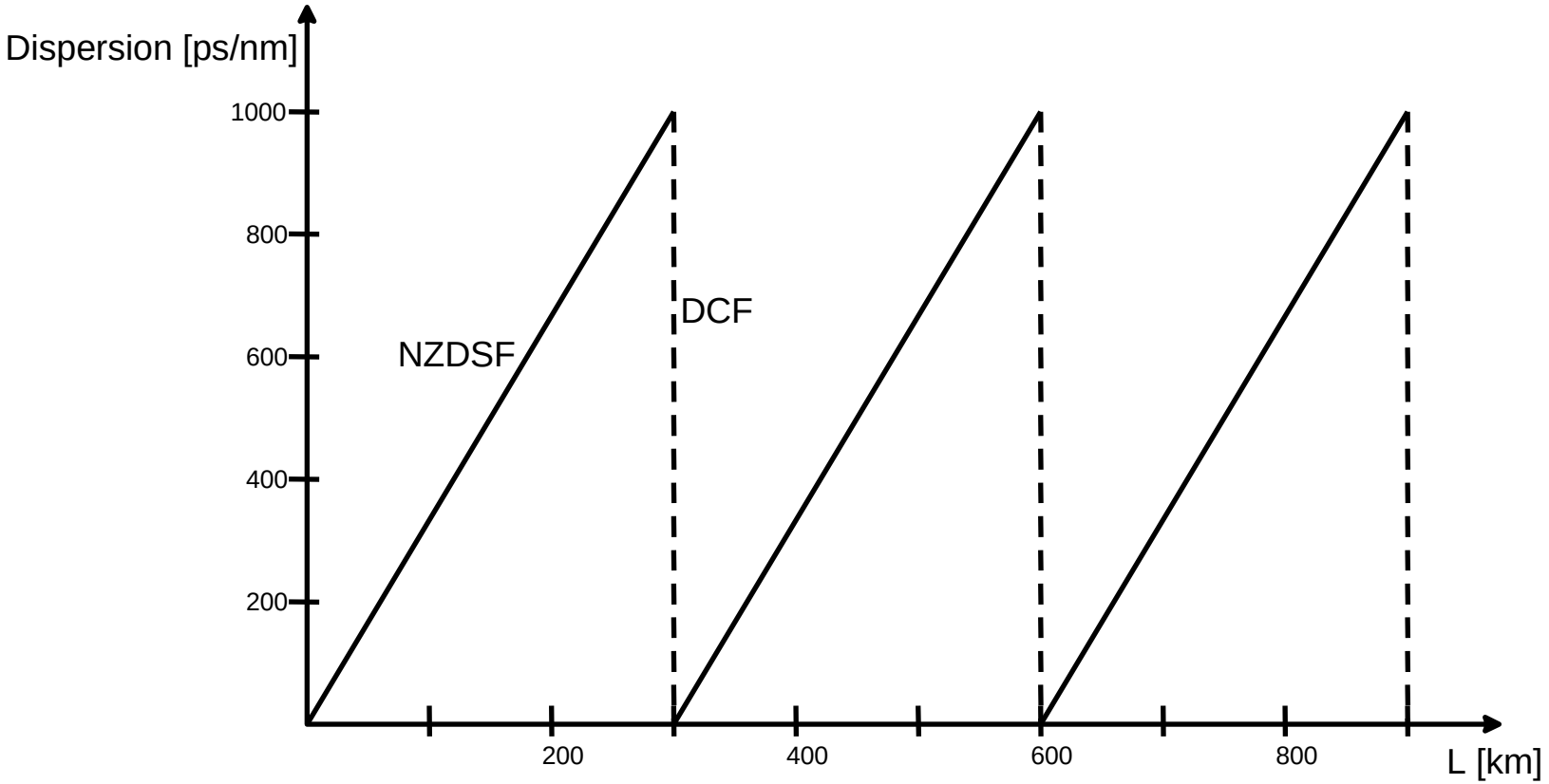
2. Decreasing impulse spectral width:
   - external modulation,
   - pulse shaping of current modulation.

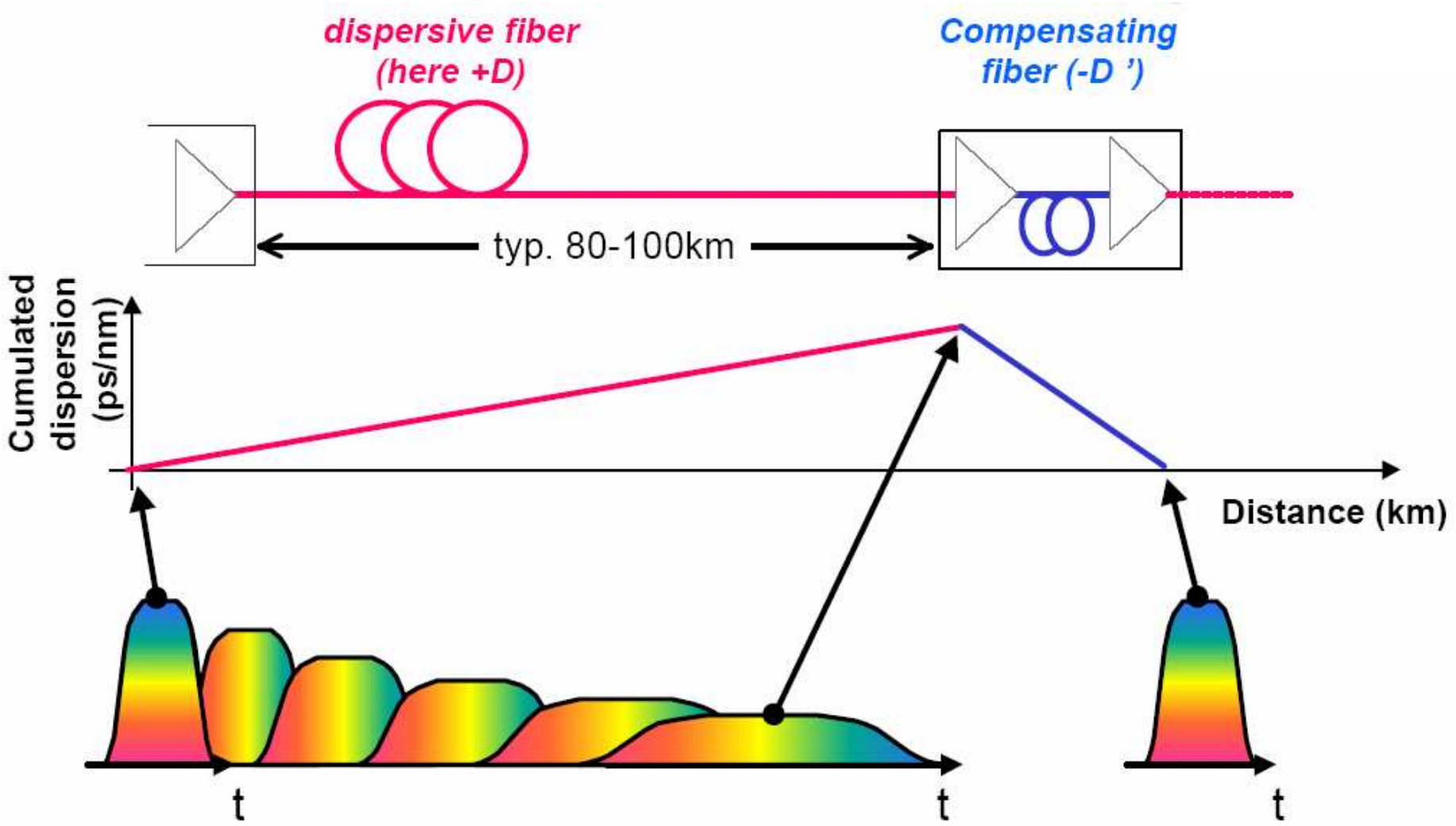
3. Soliton transmission.


δλ
λ
Dispersive
fiber
δλ
λ
Different wavelengths travel
at different speeds
t
t

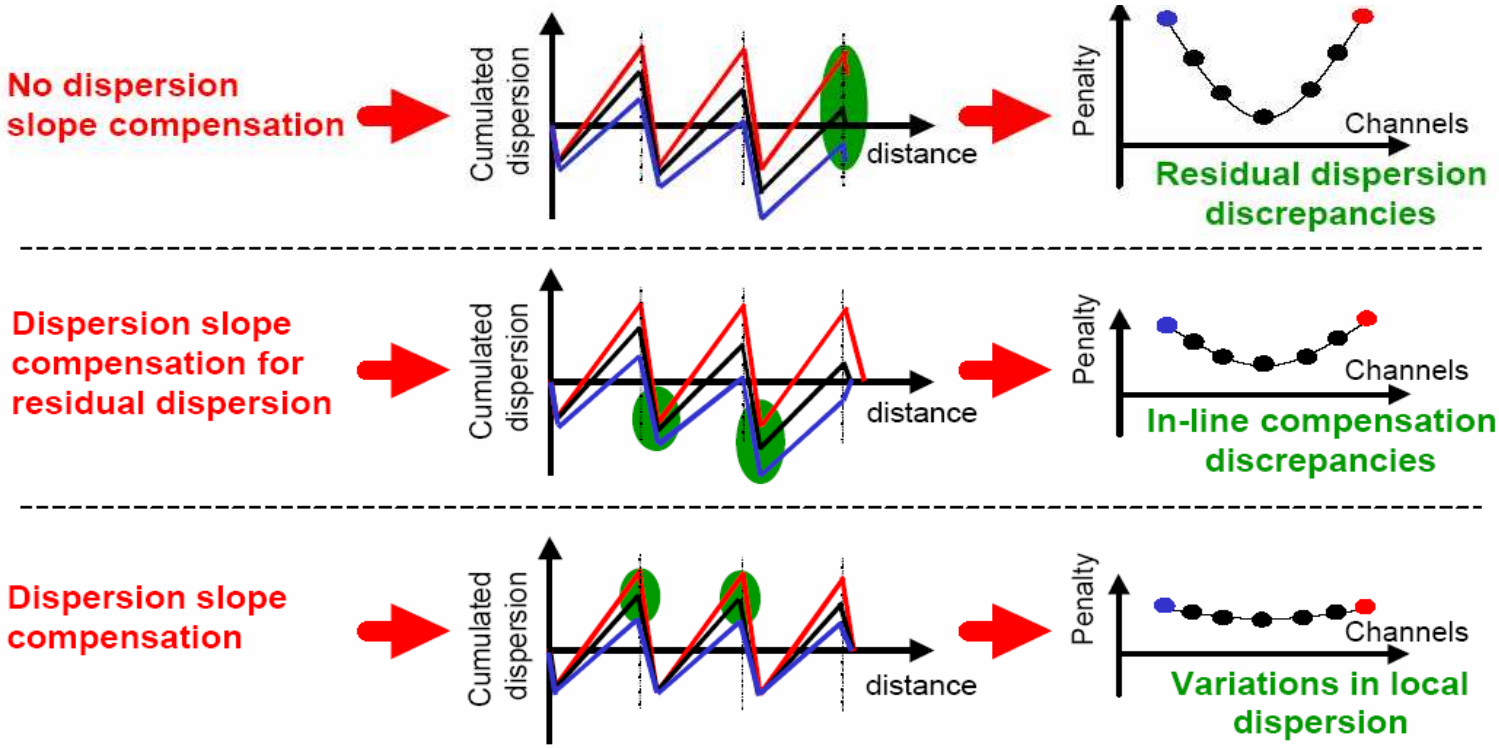
CD compensation

$$D_1L_1 - D_kL_k=0,$$

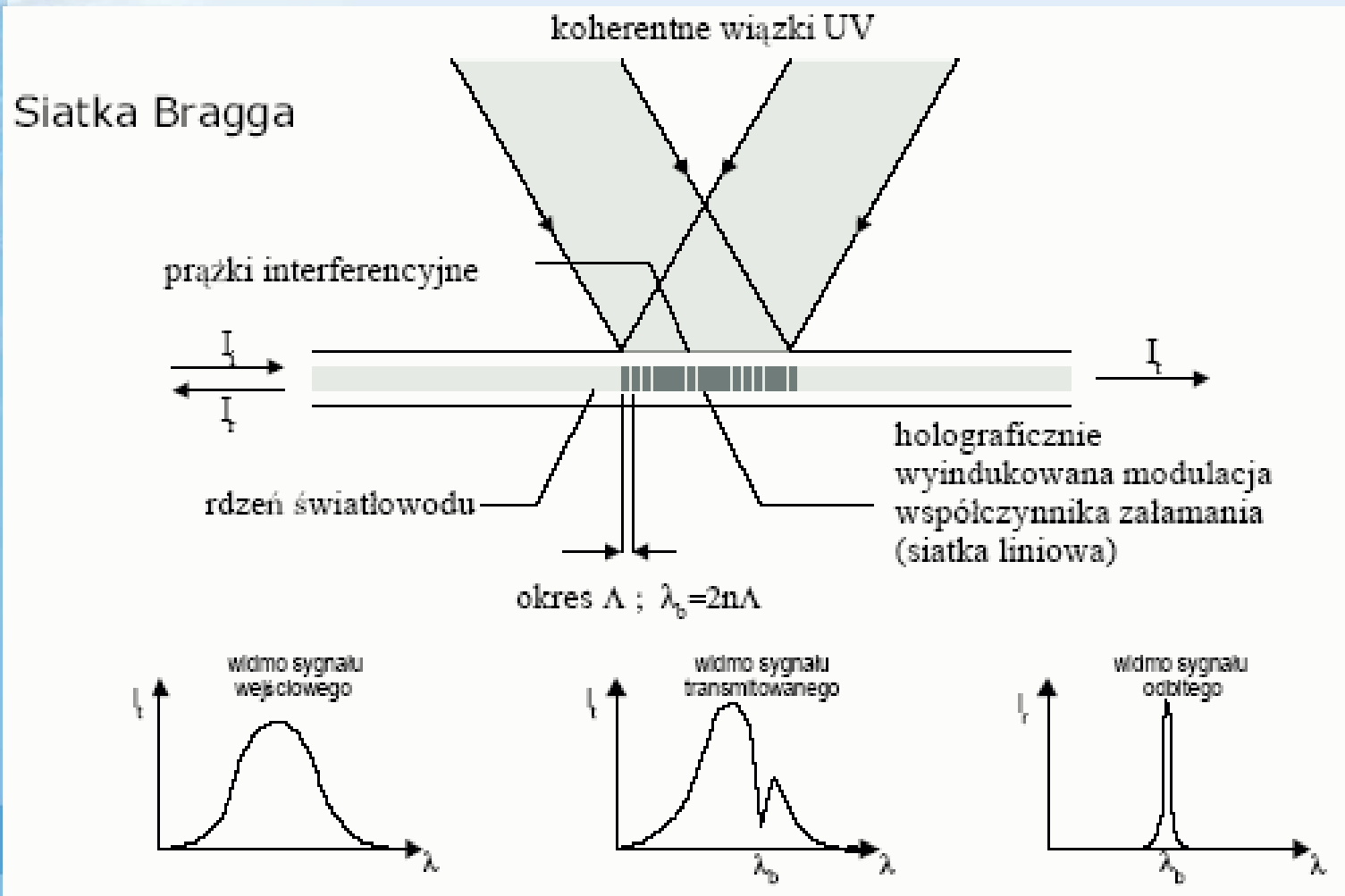



dispersive fiber
(here +D)
Compensating
fiber (-D ')
typ. 80-100km
Cumulated
dispersion
(ps/nm)
Distance (km)
t
t
t

Managing Chromatic Dispersion



Dispersion Compensation Method
Bragg gratings



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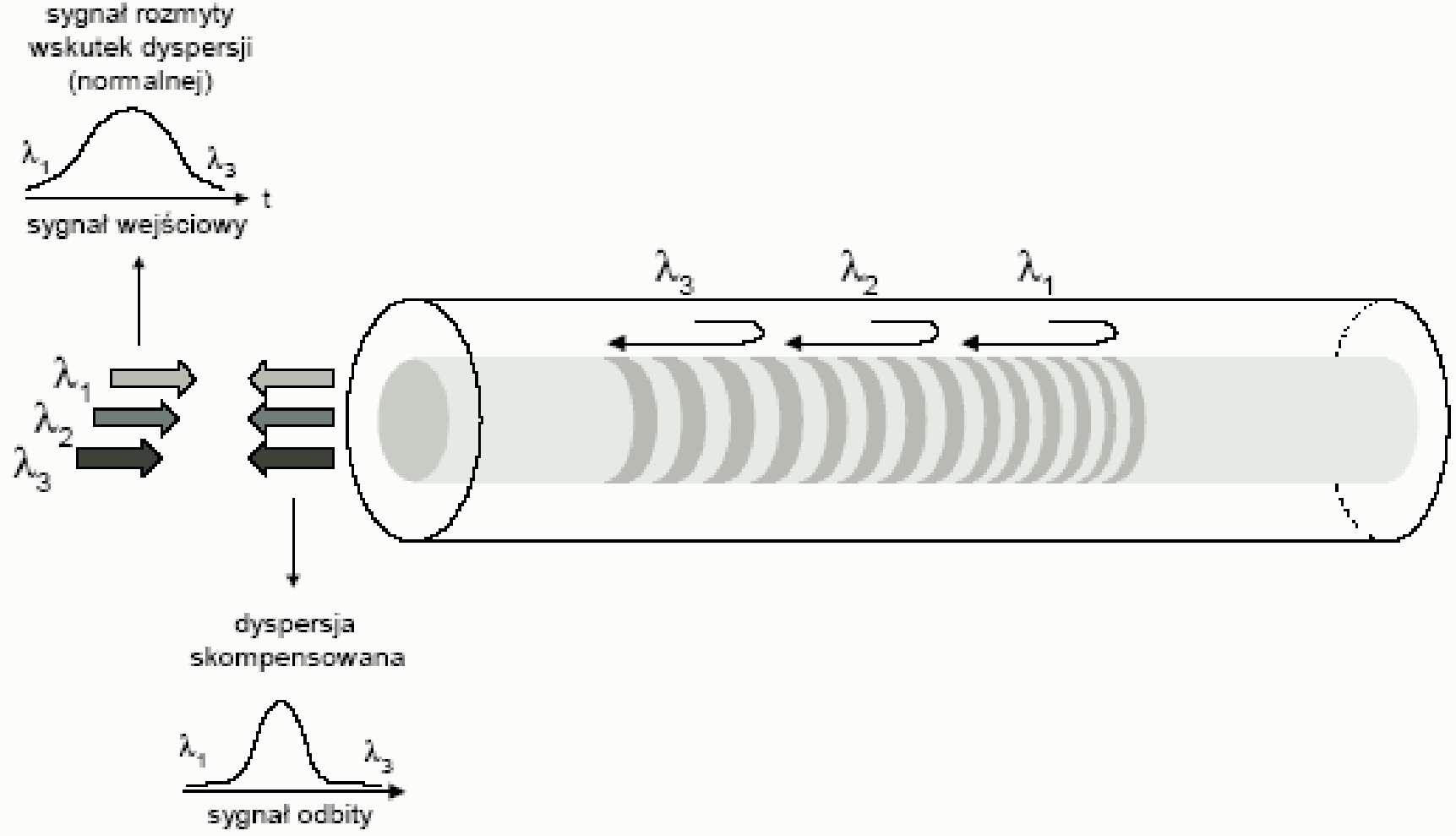
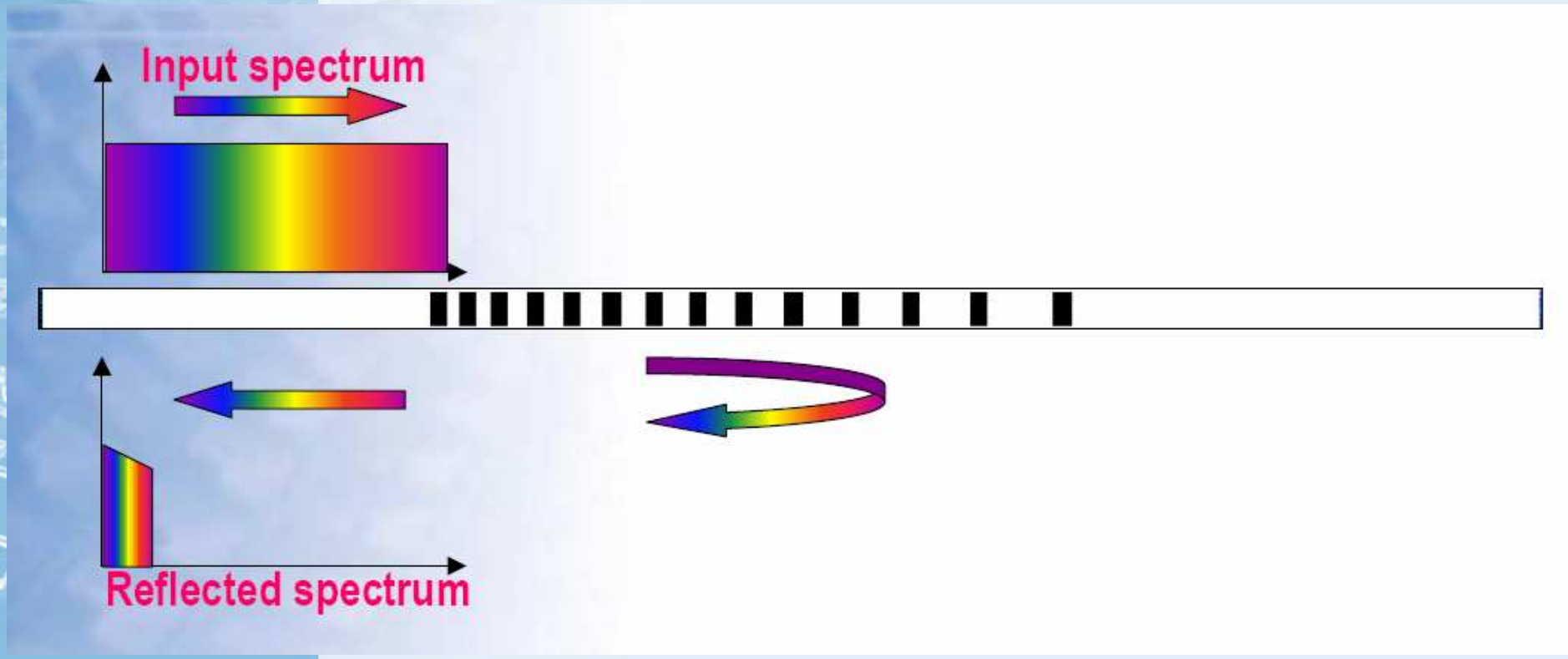
Dispersion Compensation Method
Bragg gratings




Input spectrum
Reflected spectrum

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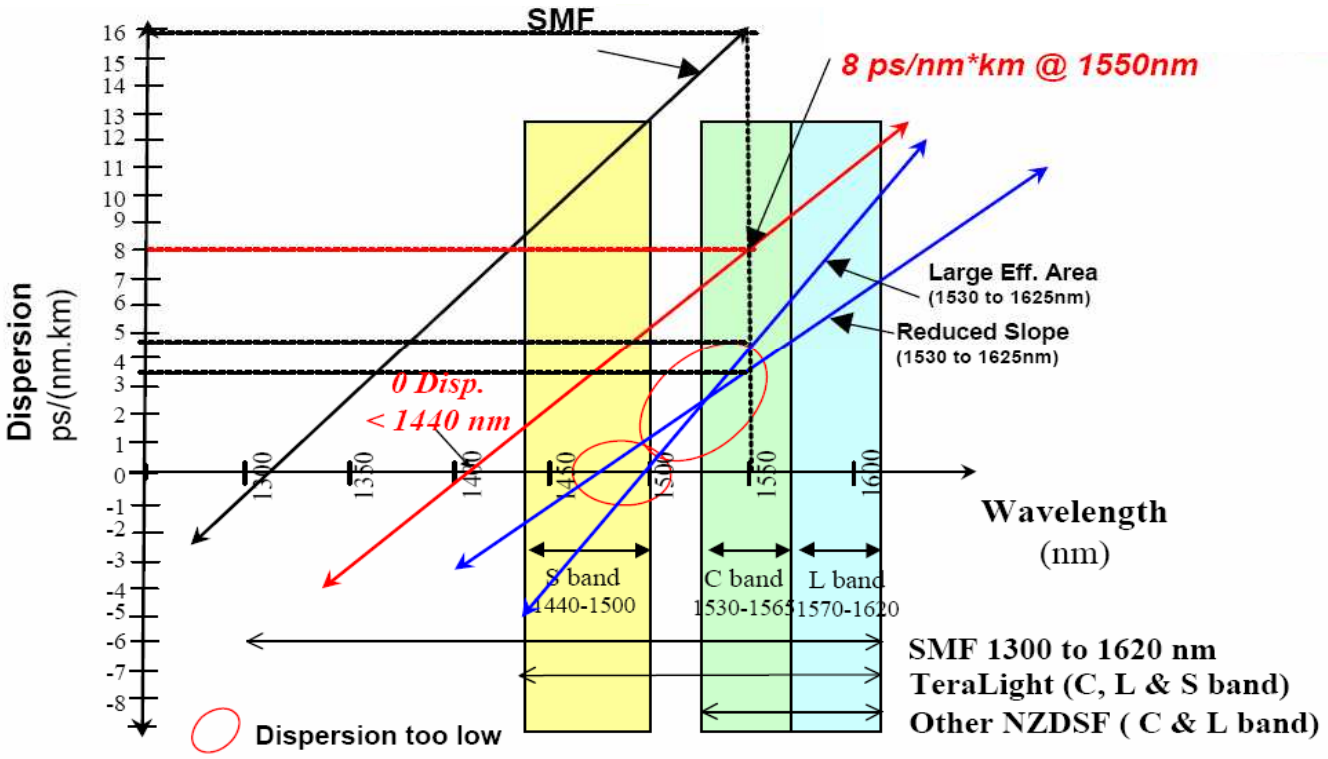
Fiber Dispersion Characteristics



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Dispersion compensation for DWDM

Summary.

Too much dispersion in a system will lead to system penalty and poor QoS.

Having zero dispersion in DWDM systems leads to system impairments from fibre non-linearities such as Four Wave Mixing.

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