Optical Fiber Communications

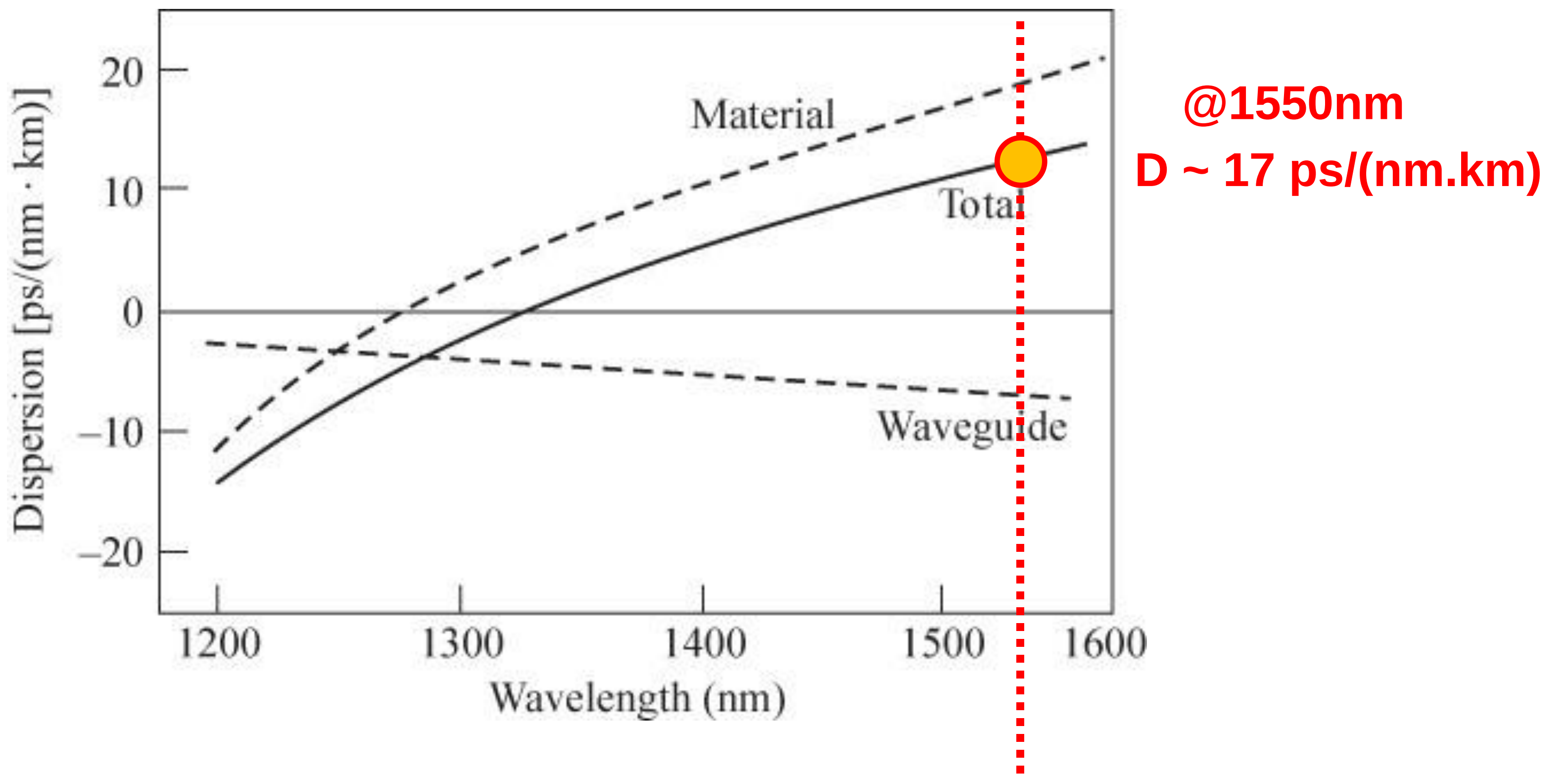
Chapter 3

Dispersion

Dispersion in SMF

Dispersion Effects

Dispersion Characteristics for SMF (Single Mode Fiber)

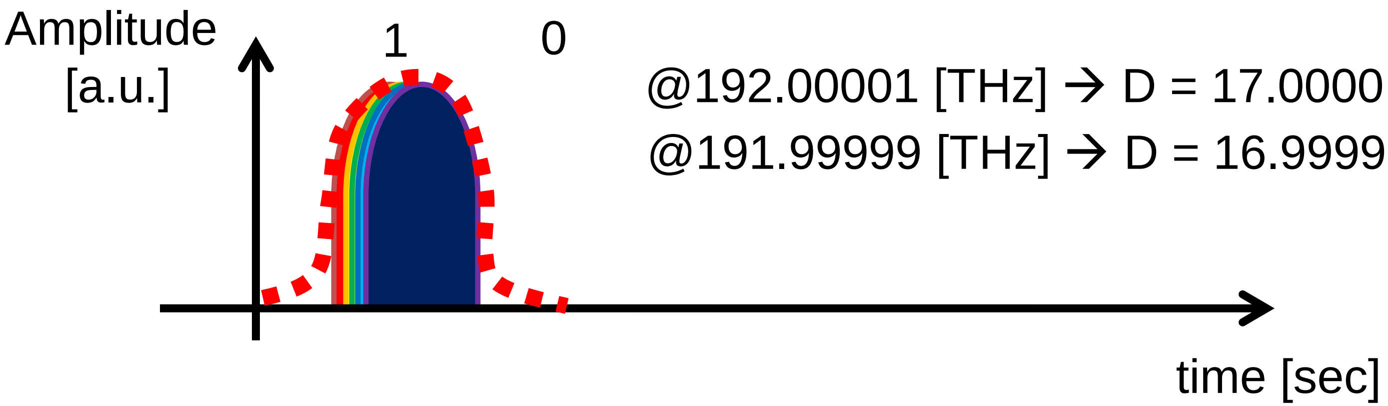


(Chromatic) Dispersion is wavelength dependent.

Optical Signal Propagation (Single Pulse)

Dispersion Effects

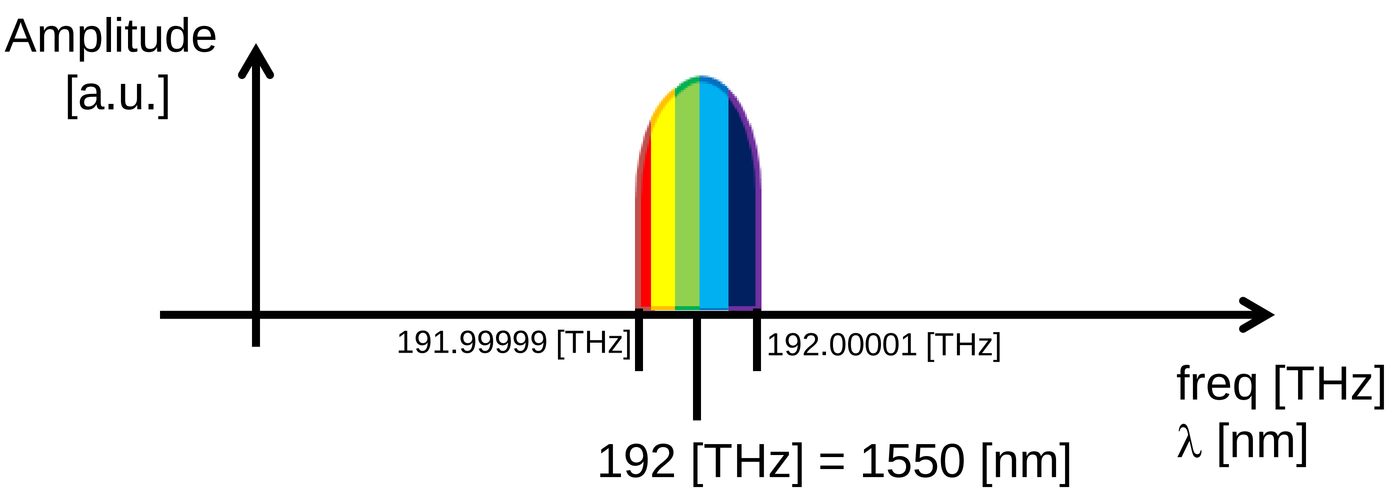
Optical Signal Representation in “Time Domain”



@192.00001 [THz] → D = 17.0000 ps/km

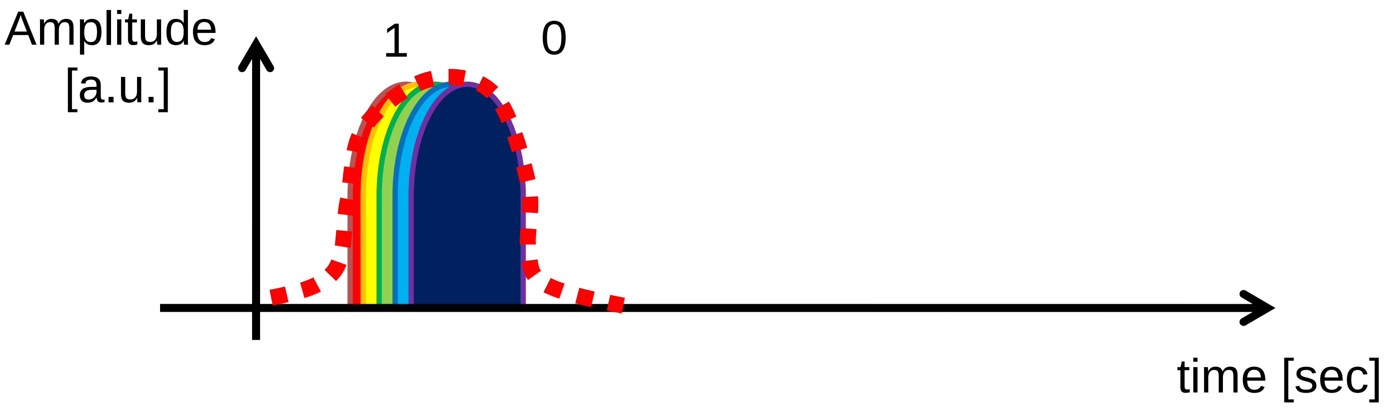
@191.99999 [THz] → D = 16.9999 ps/km

Optical Signal Representation in “Freq (wavelength) Domain”

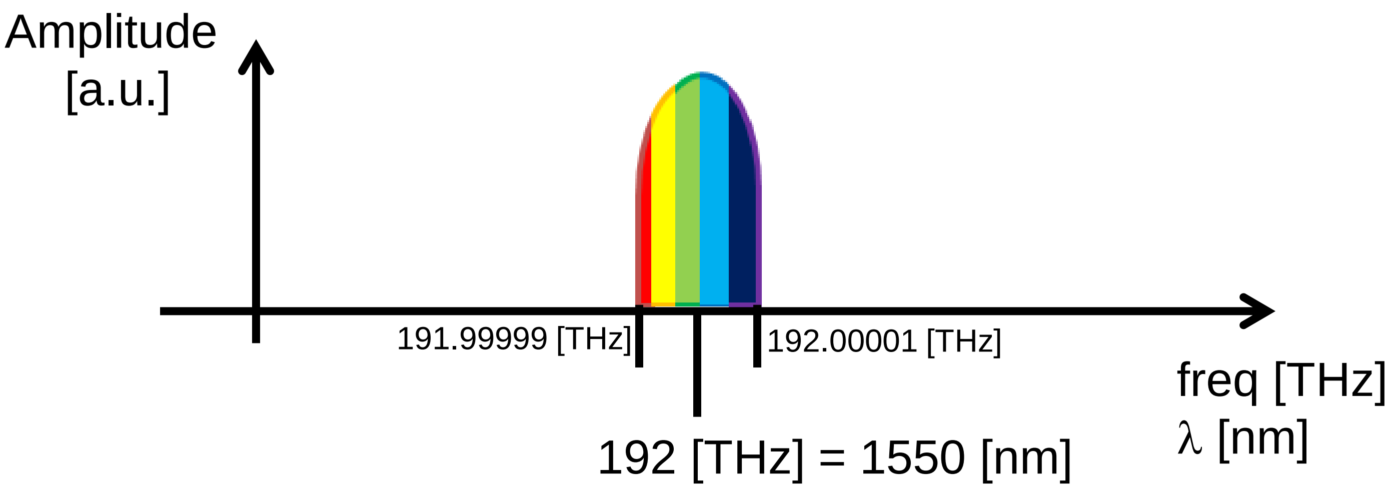


Dispersion Effects

Optical Signal Representation in “Time Domain”

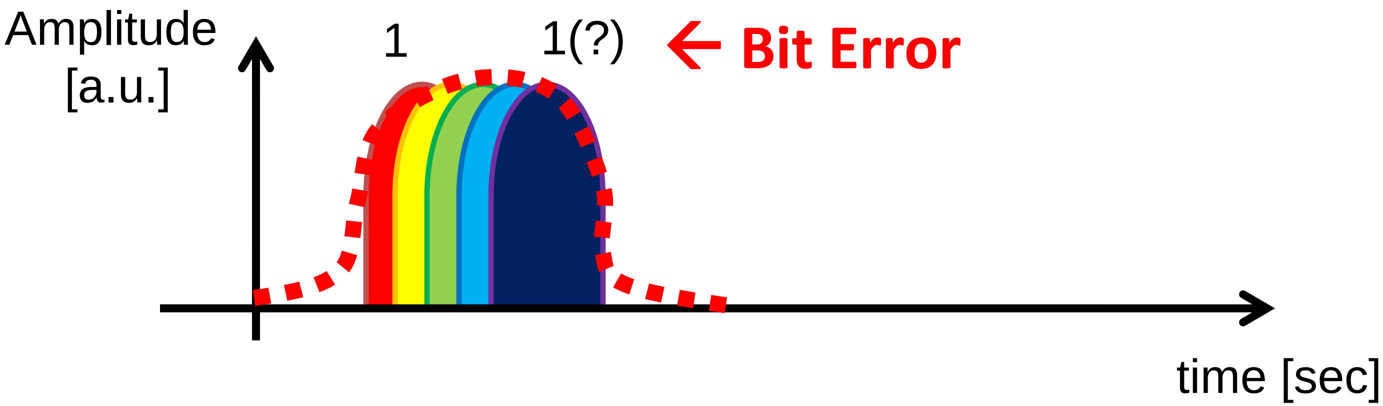


Optical Signal Representation in “Freq (wavelength) Domain”

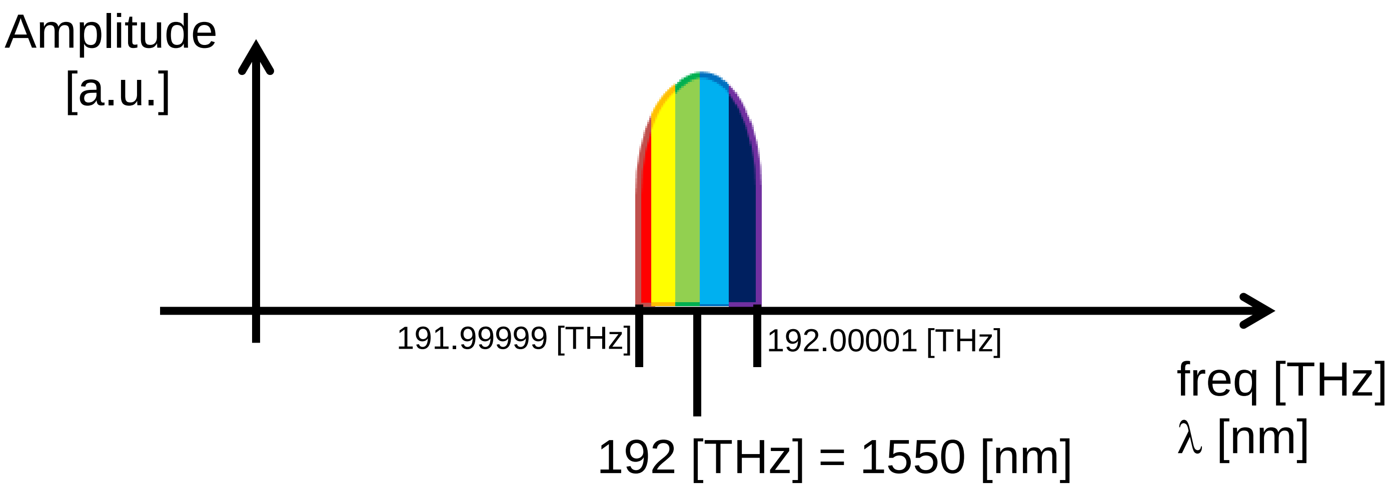


Dispersion Effects

Optical Signal Representation in “Time Domain”

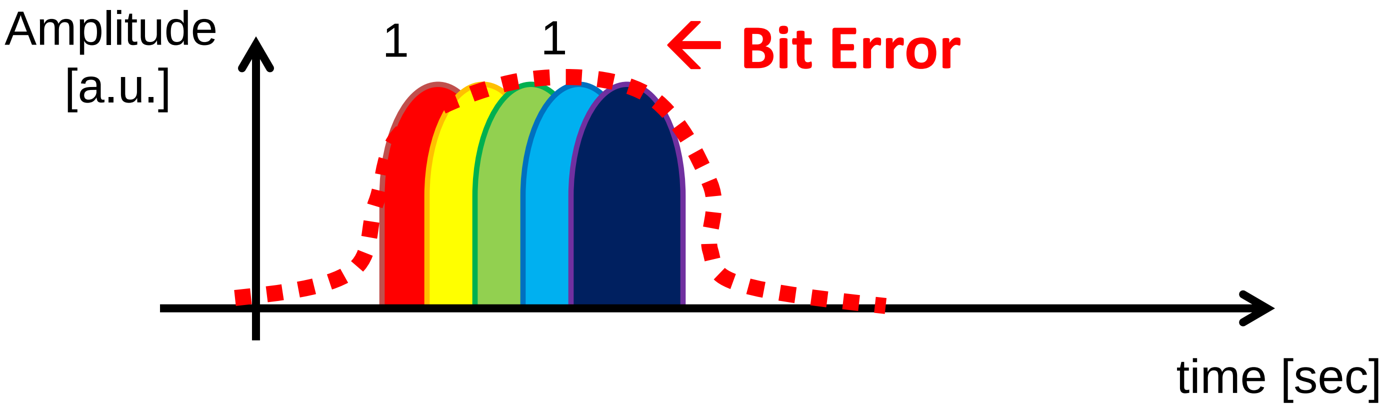


Optical Signal Representation in “Freq (wavelength) Domain”

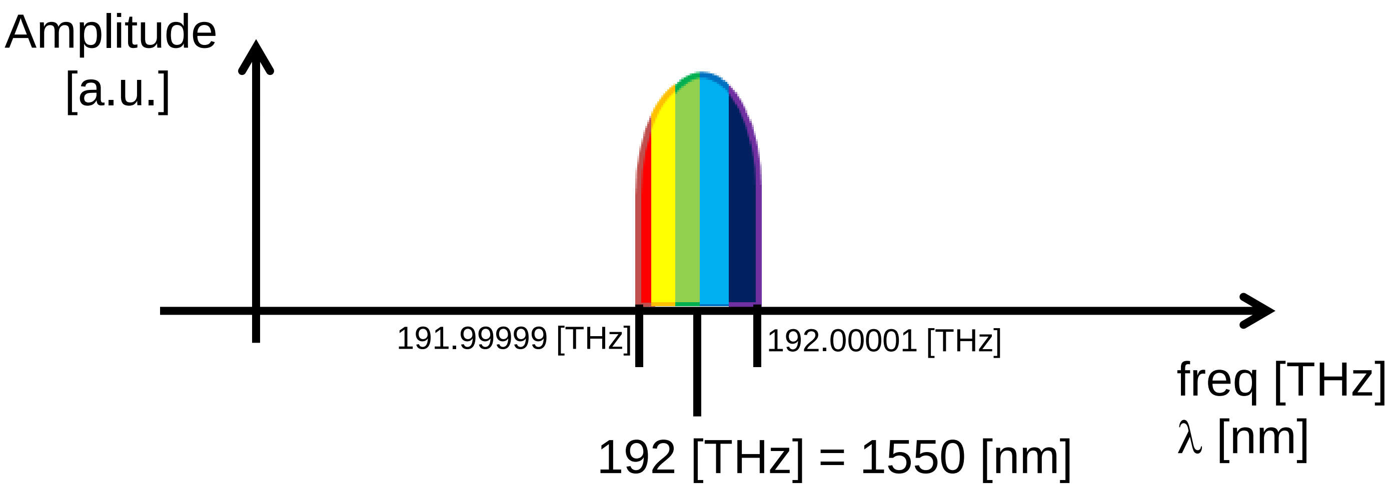


Dispersion Effects

Optical Signal Representation in “Time Domain”



Optical Signal Representation in “Freq (wavelength) Domain”



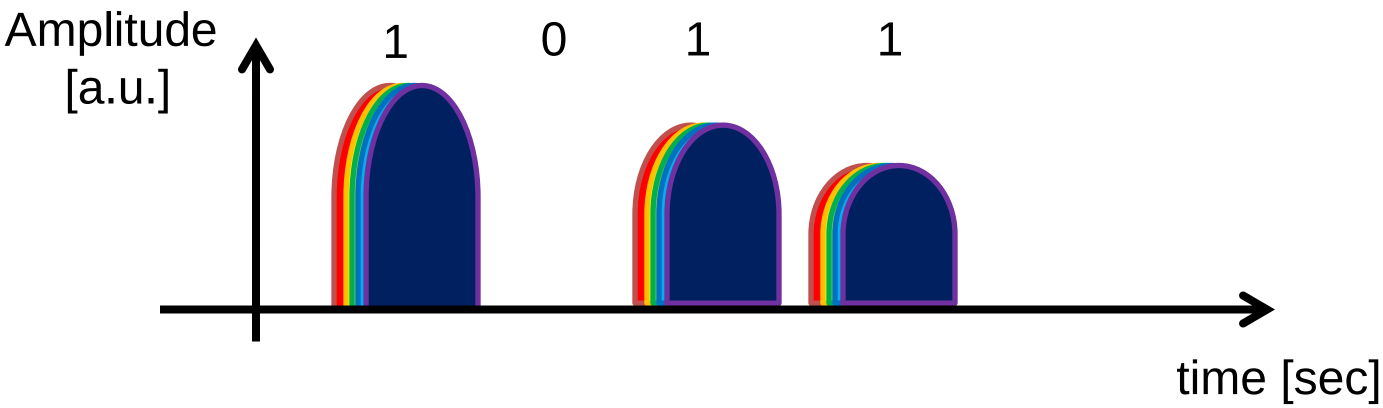
Optical Signal Propagation

(Multiple Pulses)

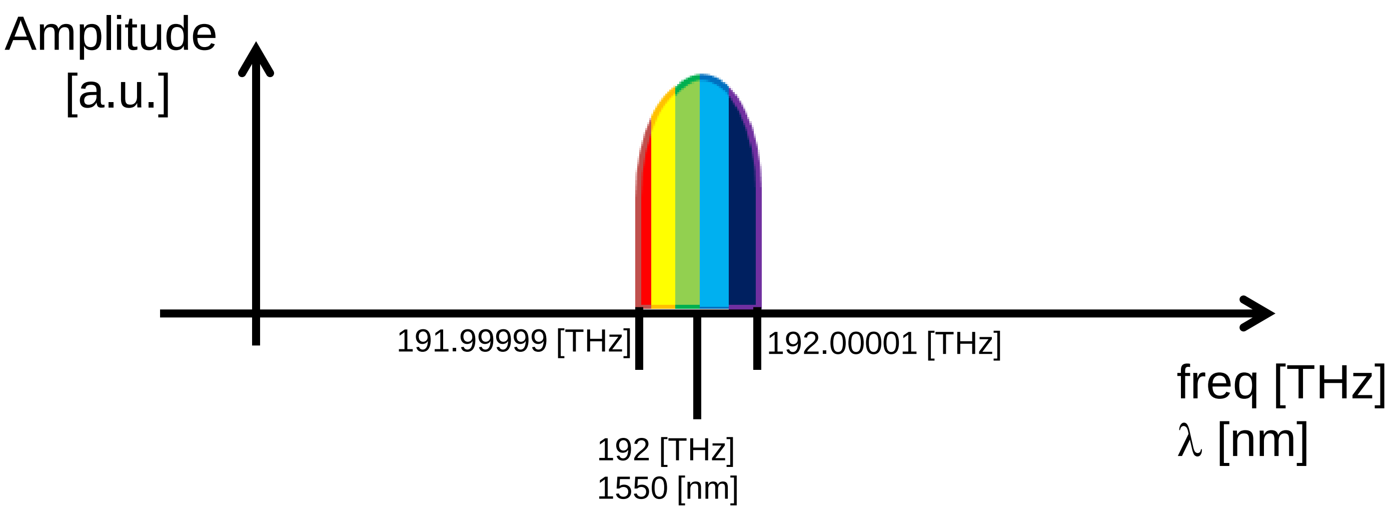
(Data Stream)

Dispersion Effects

Optical Signal Representation in “Time Domain”

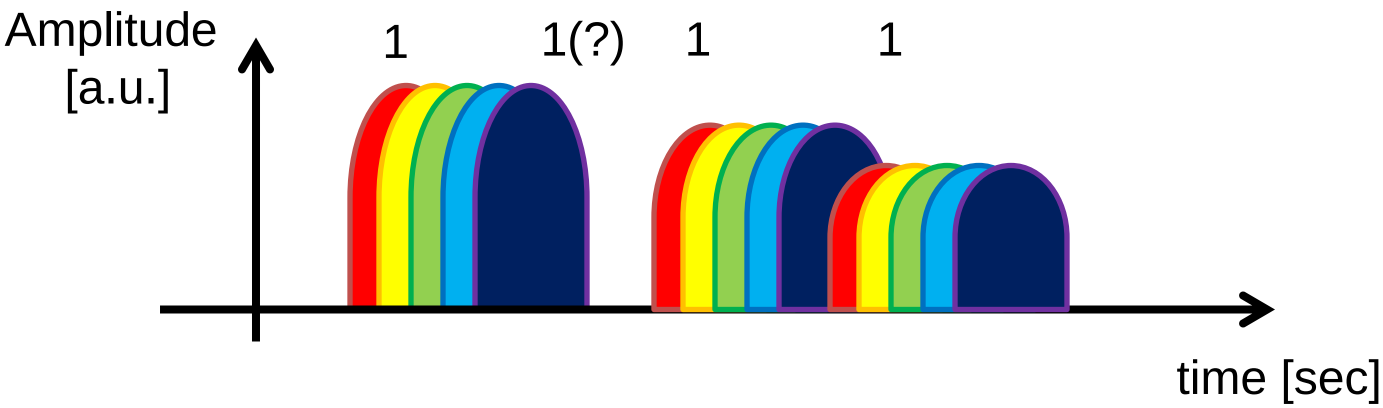


Optical Signal Representation in “Freq (wavelength) Domain”

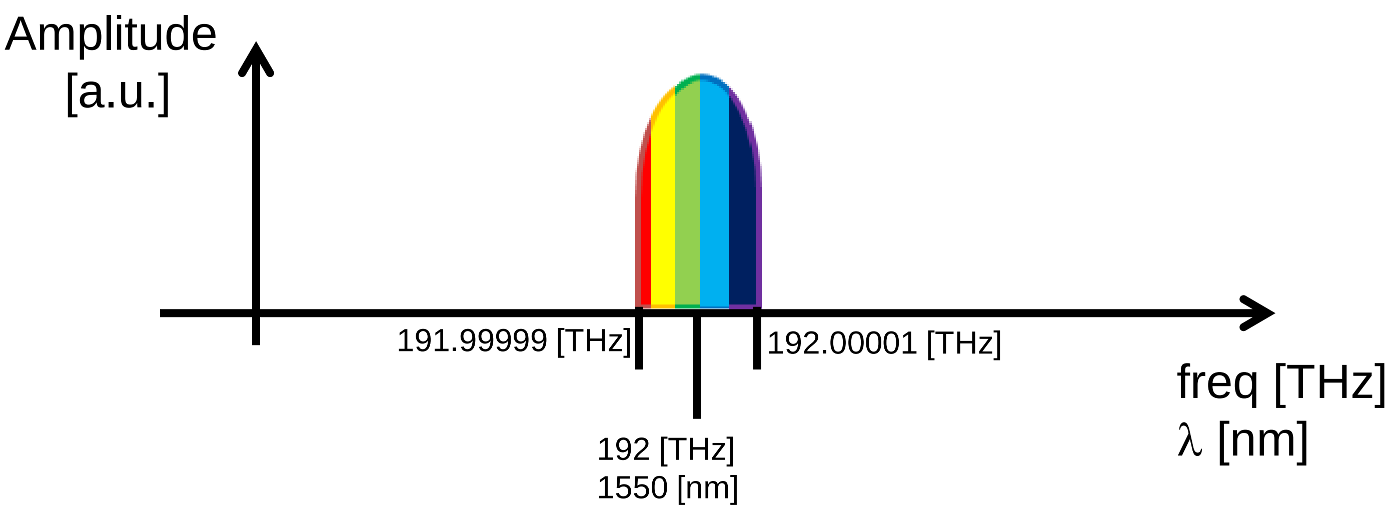


Dispersion Effects

Optical Signal Representation in “Time Domain”

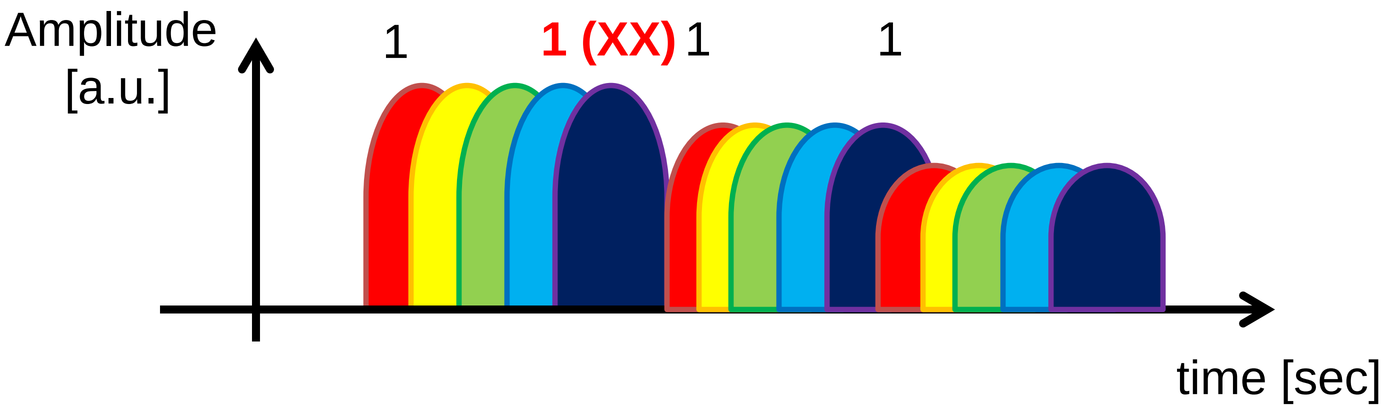


Optical Signal Representation in “Freq (wavelength) Domain”

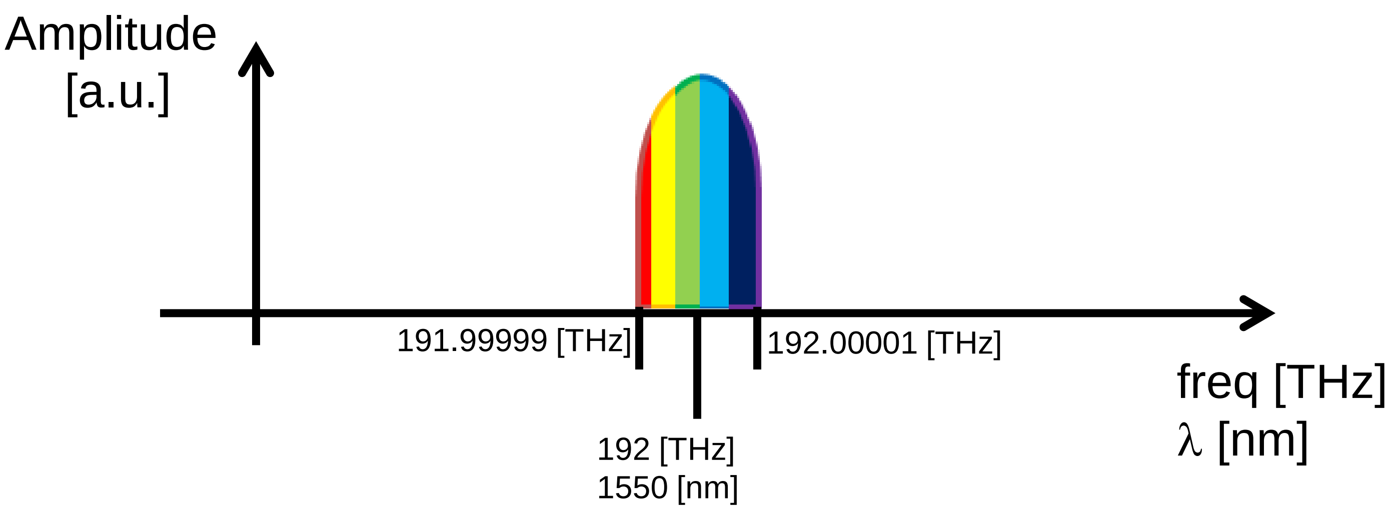


Dispersion Effects

Optical Signal Representation in “Time Domain”

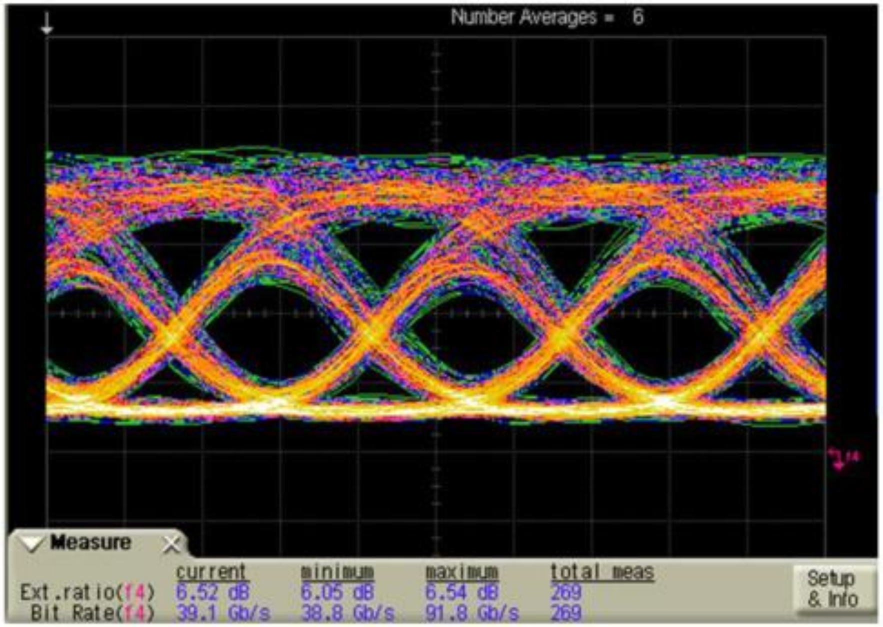


Optical Signal Representation in “Freq (wavelength) Domain”



Eye Diagram

- Overlays for different logics
- Can be viewed as repeated oscilloscope display
- Provides good measure of dispersion (shown in next slides)



https://www.youtube.com/watch?v=bbyQjqOooq0

Dispersion compensation example

Transmission fiber

Positive dispersion
(Negative dispersion)

Longer wavelength ⇨ Slow (Fast)

Shorter wavelength ⇨ Fast (Slow)

+

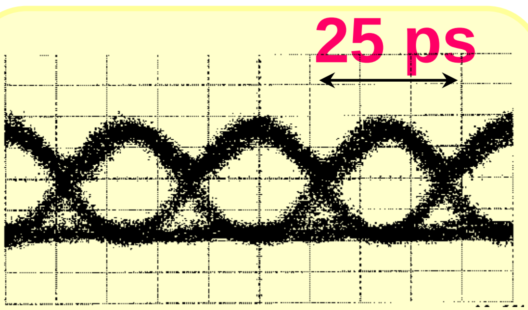
Dispersion compensating fiber (DCF)

Negative dispersion
(Positive dispersion)

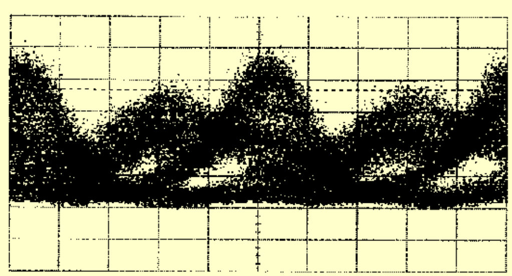
Longer wavelength ⇨ Fast (Slow)

Shorter wavelength ⇨ Slow (Fast)

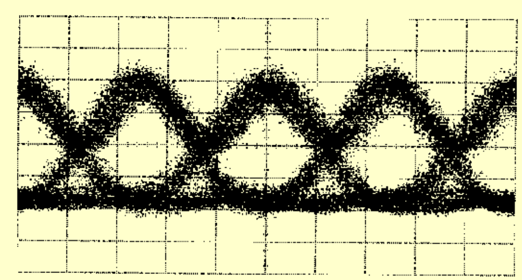
40 Gb/s optical signal



Transmitter output



After fiber transmission

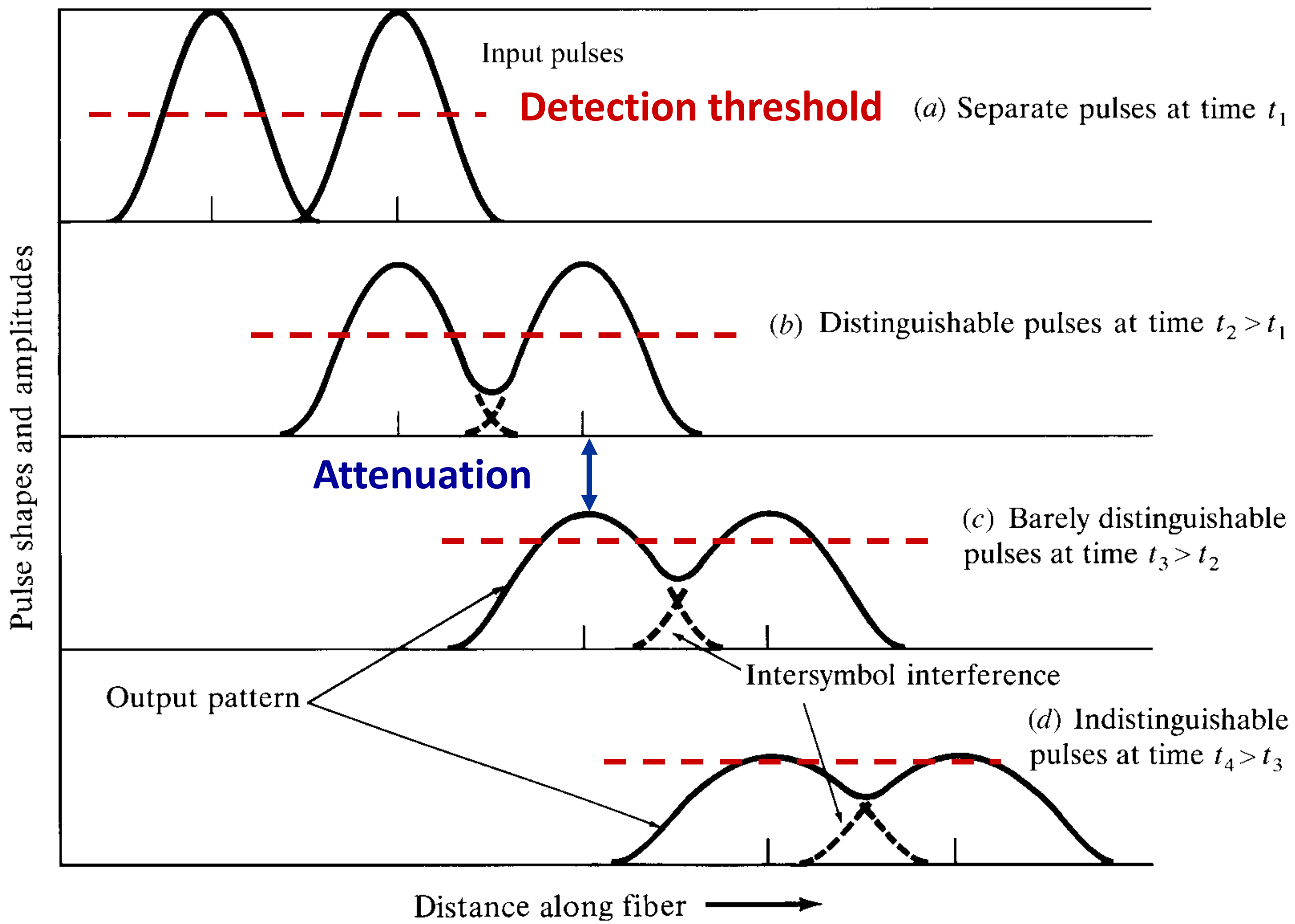


After dispersion comp.

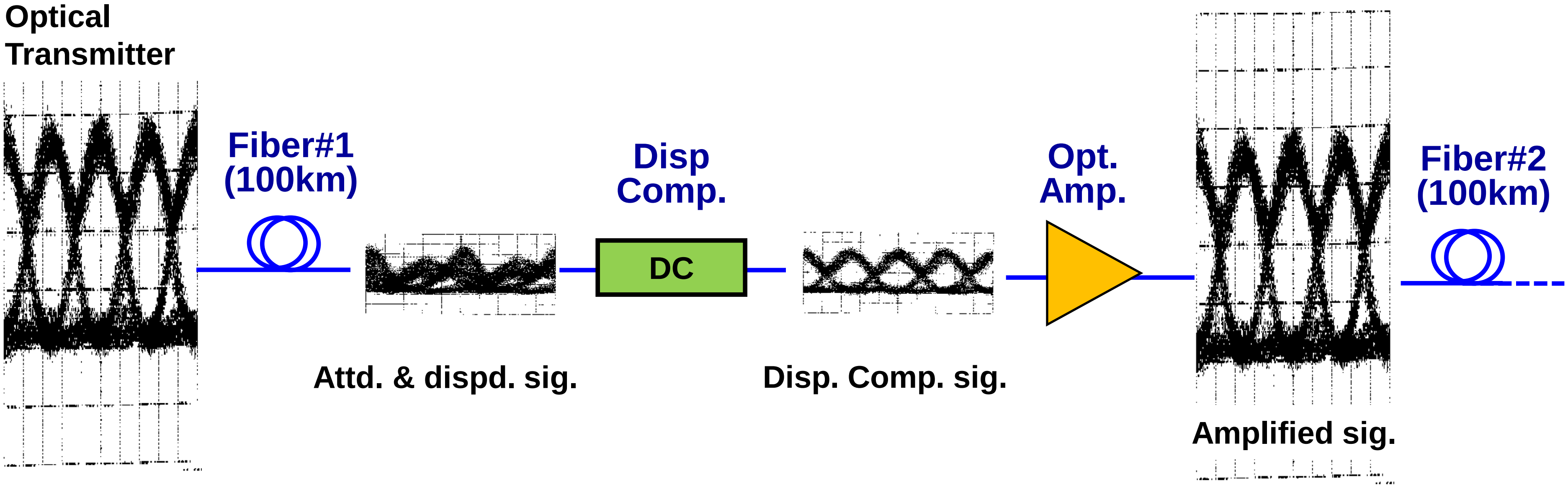
Ref : New functionalities for advanced optical interfaces (Dispersion compensation), Kazuo Yamane , Fujitsu Corp, Photonic systems development dept.

Optical Signal Propagation (Attenuation and Dispersion)

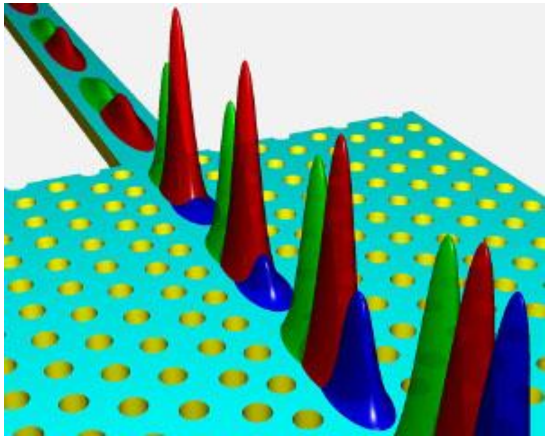
Dispersion and Attenuation Effects



Dispersion and Attenuation Effects



Micro Photonics

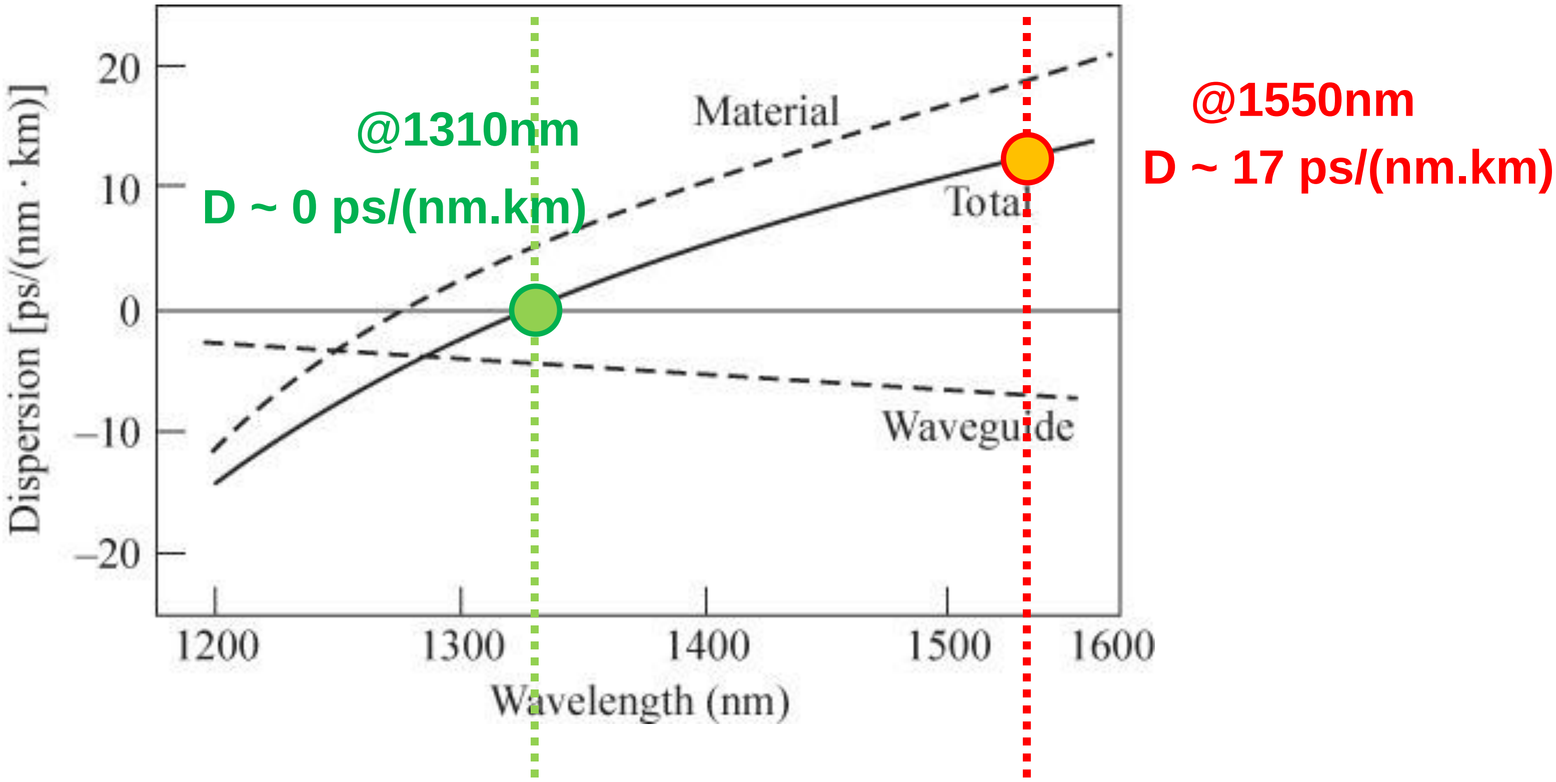


Ref : http://www.st-andrews.ac.uk/microphotonics/Projects.php

Dispersion in SMF

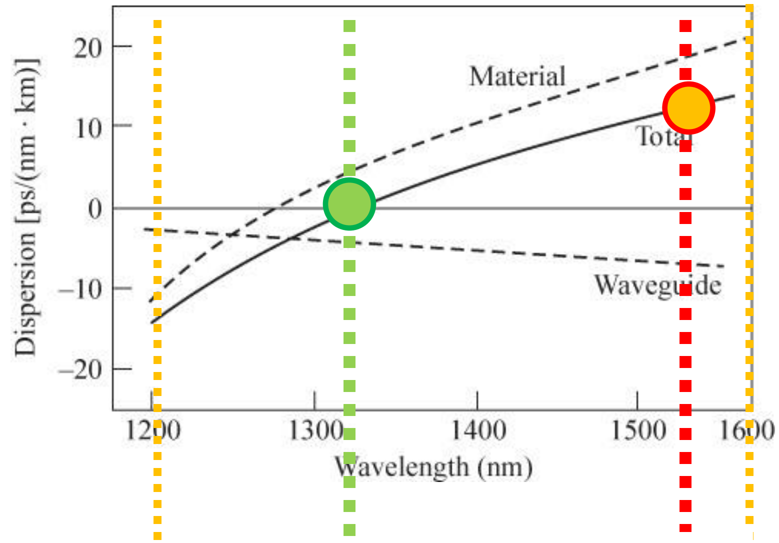
Dispersion Effects

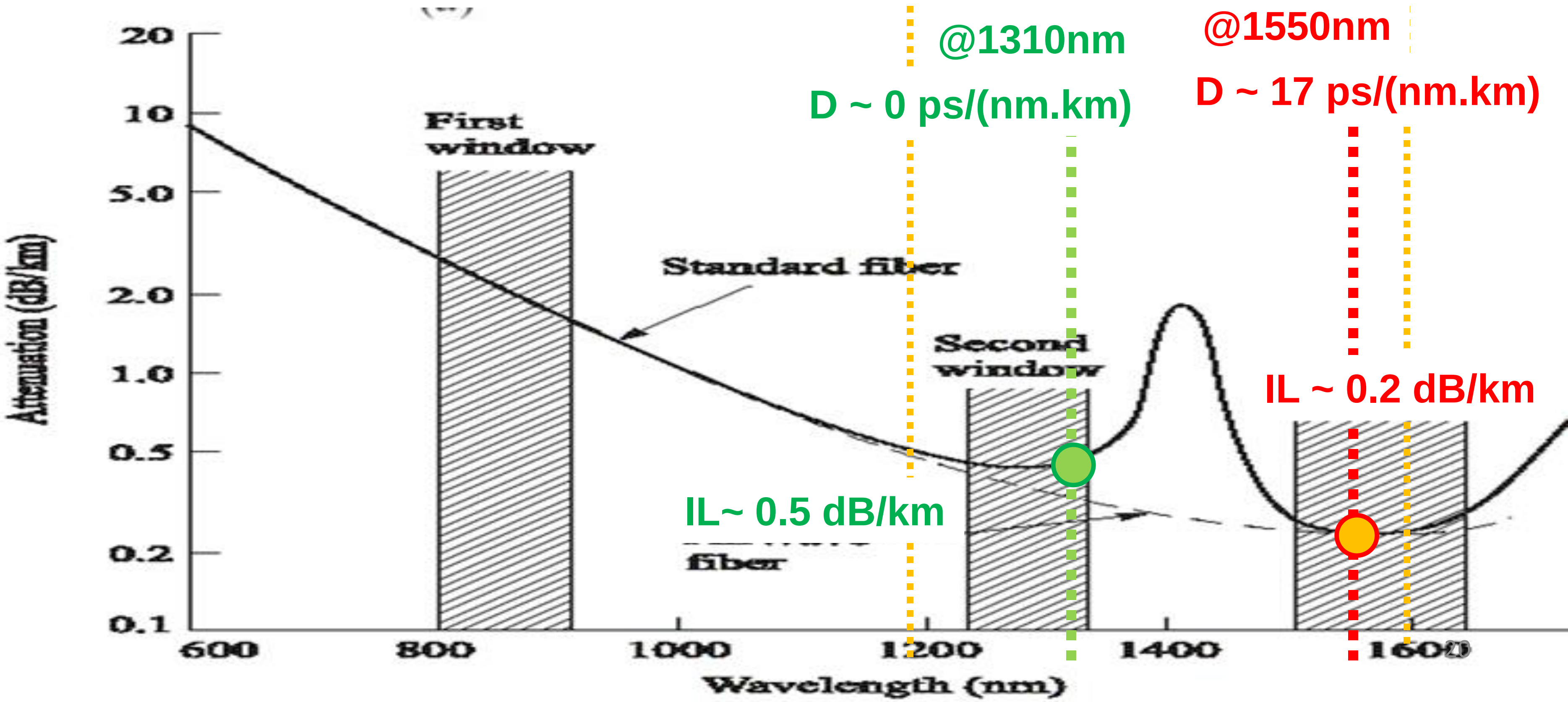
Dispersion Characteristics for SMF (Single Mode Fiber)



Why Not Use 1310-nm for long haul transmission?

Why Not Use 1310-nm for long haul transmission?

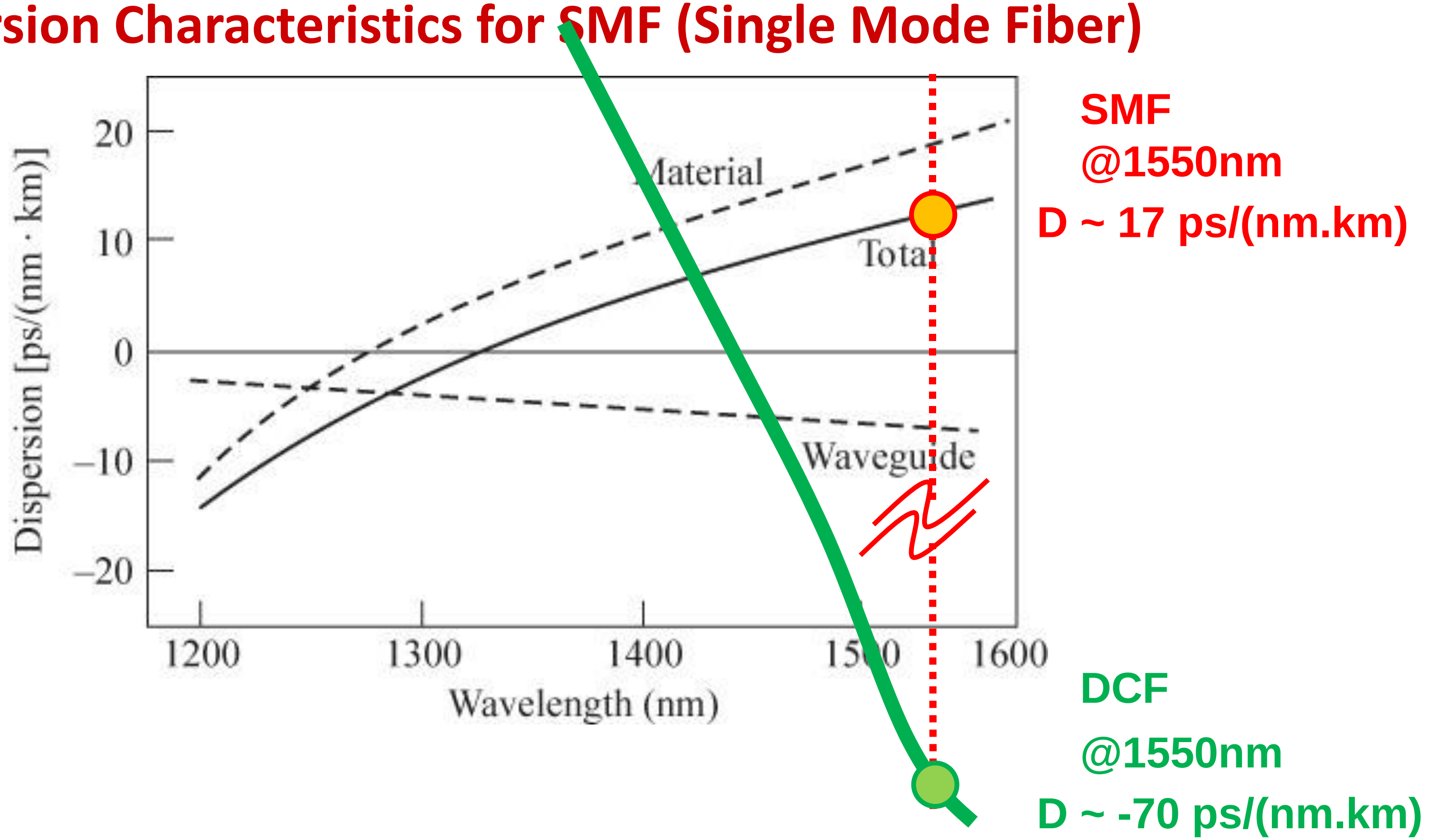




(Solution 1) Using DCF

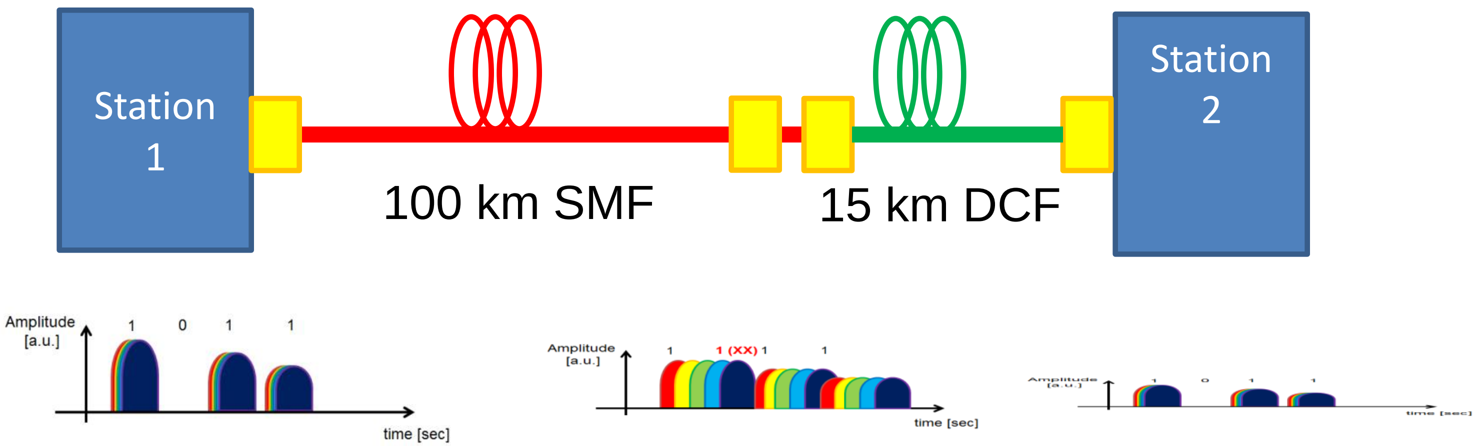
Dispersion Effects

Dispersion Characteristics for SMF (Single Mode Fiber)



What will happen to pulses if you have special fiber with dispersion parameter in "opposite polarity"?

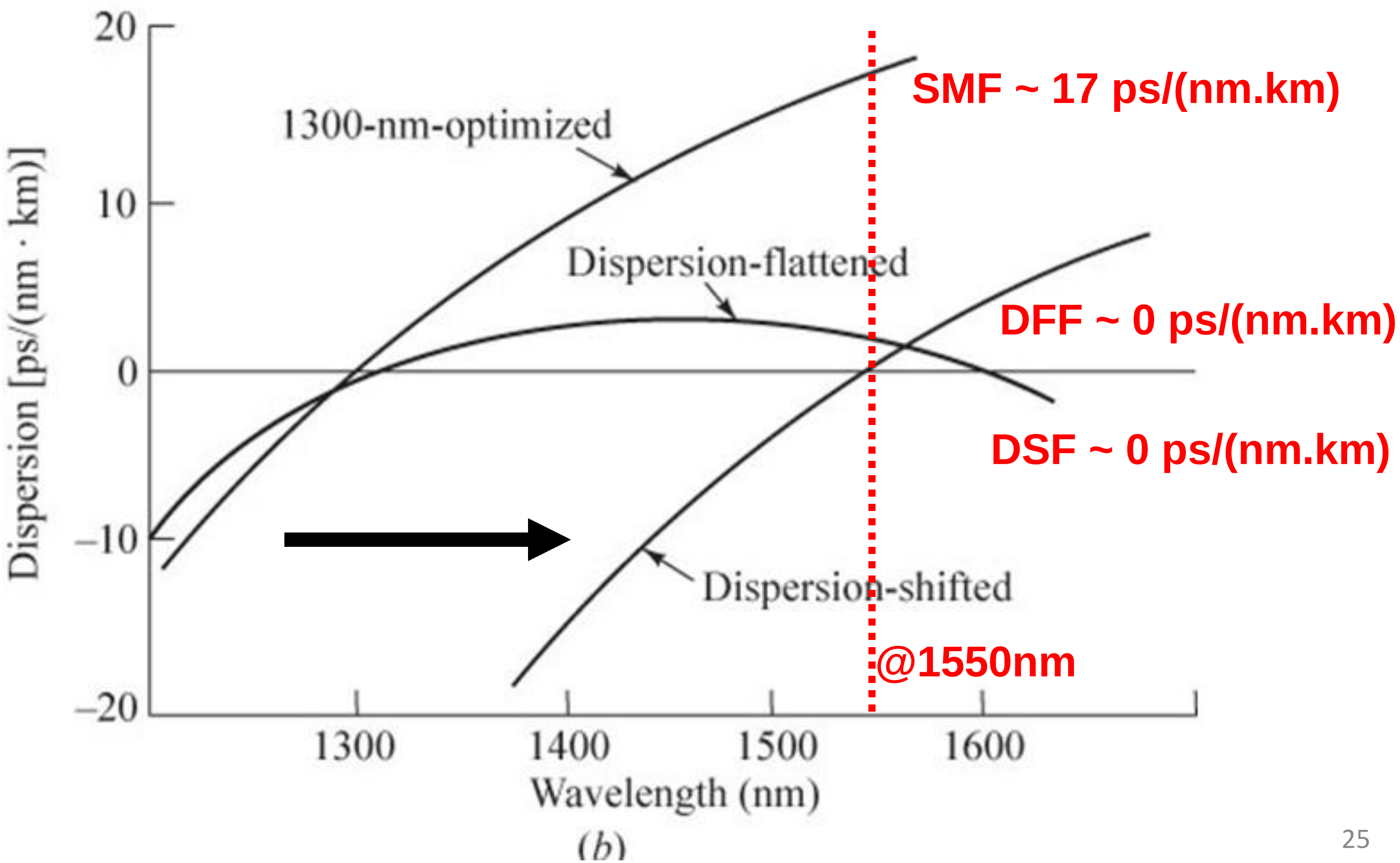
Fiber Communication System Config.



(Solution 2) Using DSF, (NZDSF), DFF

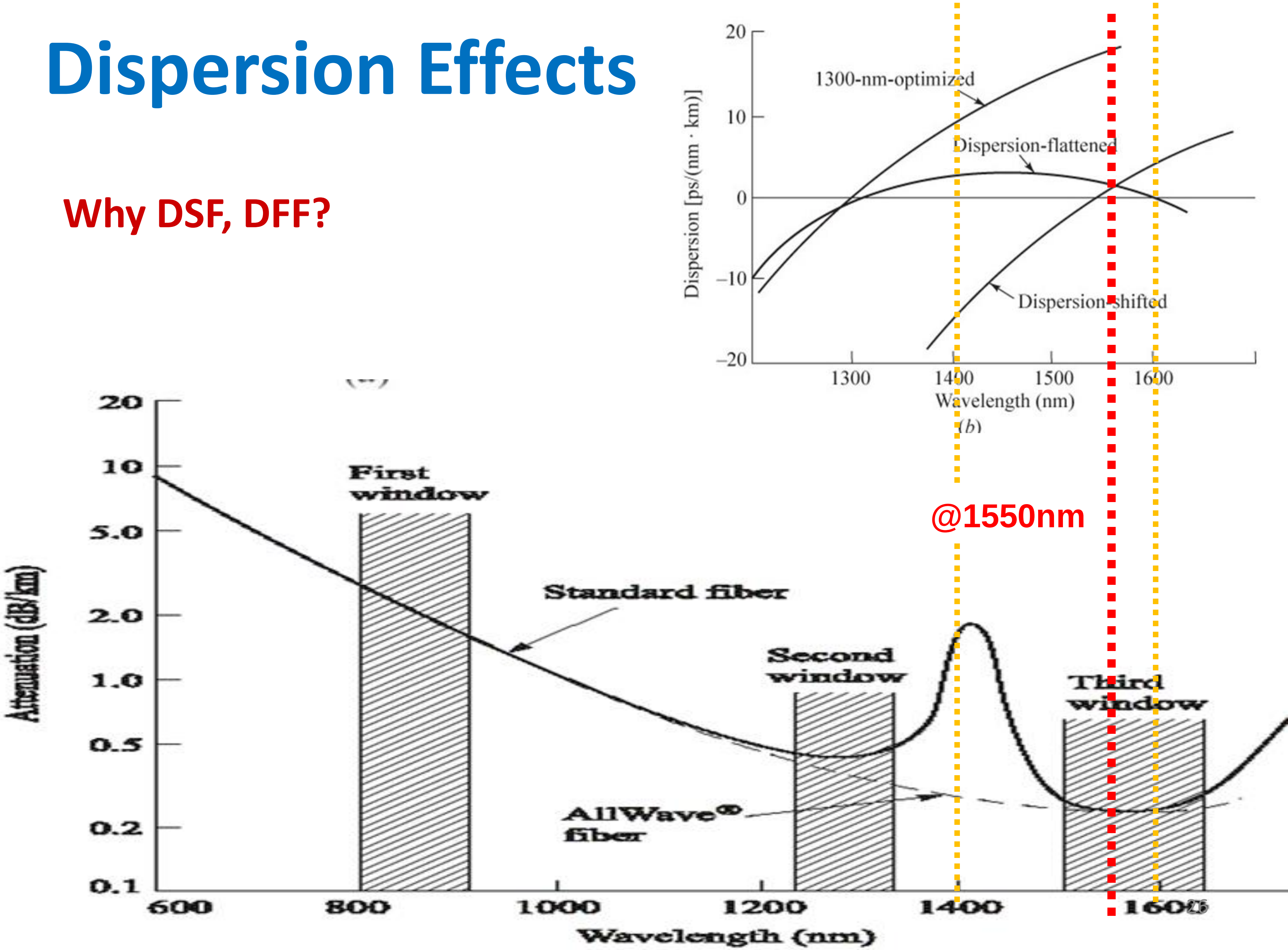
Dispersion Effects

Dispersion Characteristics for SMF, DSF, DFF



Dispersion Effects

Why DSF, DFF?



(Example) Optical Signal Propagation

(Dispersion and Compensation Example)

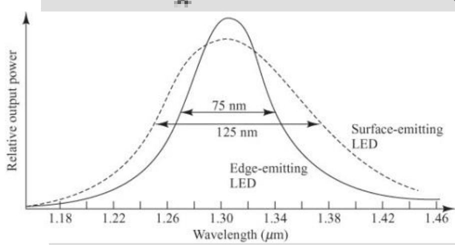
Material Dispersion Comparison

LED source

Example 3.10 A manufacturer's data sheet lists the material dispersion D_{mat} of a GeO_2-doped fiber to be 110 ps/(nm · km) at a wavelength of 860 nm. Find the rms pulse broadening per kilometer due to material dispersion if the optical source is a GaAlAs LED that has a spectral width σ_λ of 40 nm at an output wavelength of 860 nm.

Solution: From Eq. (3.28) we find that the rms material dispersion is

$$\sigma_{mat}/L = \sigma_\lambda D_{mat} = (40\text{ nm}) \times [110\text{ ps/(nm} \cdot \text{km)}] = 4.4\text{ ns/km}$$



40nm

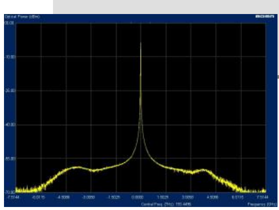
Laser diode source

Example 3.11 The manufacturer's data shows that the same fiber as in Example 3.10 has a material dispersion D_{mat} of 15 ps/(nm · km) at a wavelength of 1550 nm. However, now suppose we use a laser source with a spectral width σ_λ of 0.2 nm at an operating wavelength of 1550 nm. What is the rms pulse broadening per kilometer due to material dispersion in this case?

Solution: From Eq. (3.28) we find that the rms material dispersion is

$$\sigma_{mat}/L = \sigma_\lambda D_{mat} = (0.2\text{ nm}) \times [15\text{ ps/(nm} \cdot \text{km)}] = 7.5\text{ ps/km}$$

This example shows that a dramatic reduction in dispersion can be achieved when operating at longer wavelengths with laser sources.



0.2nm