smartoptics

Optical fibre transmission:

How to cram bits into fibres

Kent Lidström

April 1, 2022

Agenda

Wavelength Divisioning Multiplexing basics
- Fiber
- Transceivers
- WDM intro

Transmission Challenges
- Fiber loss
- Fiber dispersion
- OSNR

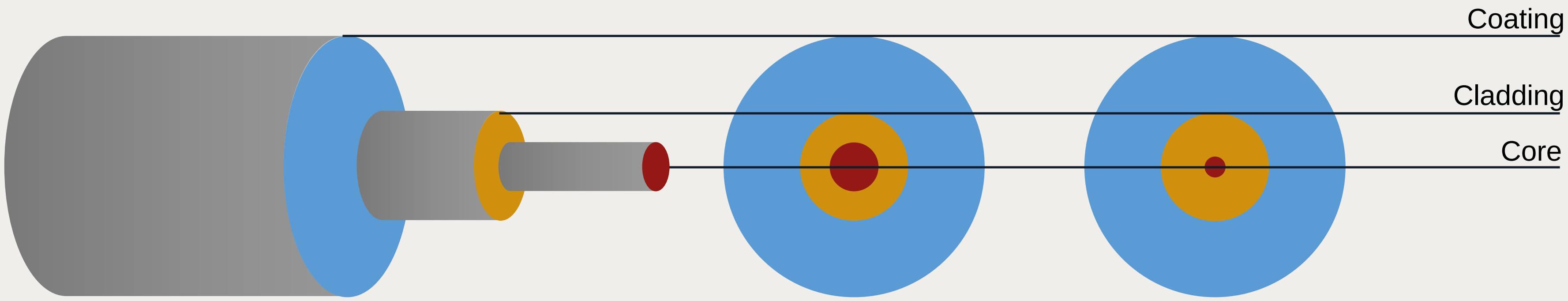
Modulation formats
- NRZ
- PAM4
- Coherent

Optical Solutions
- Line Systems
- Transponders and Muxponders

smartoptics

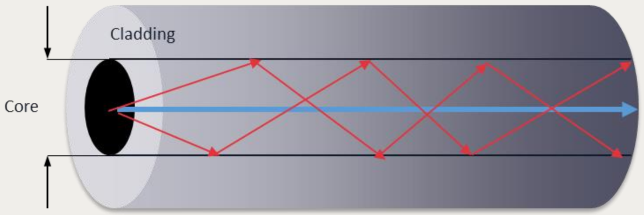
smartoptics

Optical Fiber



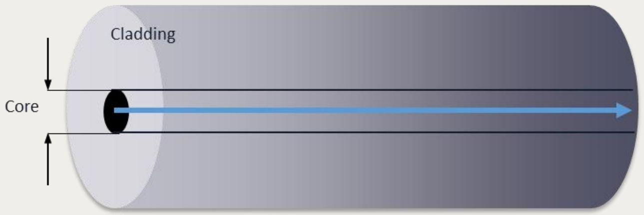
	Multimode fiber	**Singlemode fiber**
Coating diameter	250 µm	250 µm
Cladding Diameter	125 µm	125 µm
Core diameter	62.5 µm (Graded index) 50 µm (Step index)	9 µm

Multimode versus Single-mode fiber



Multimode signal are distributed in waves that are dispersed into numerous paths, or modes, as they travel through the cable's core: typically at 850 nm. However, in long cable run, multiple paths of light (*modal dispersion)* can cause signal distortion at the receiving end, resulting in an unclear and incomplete data transmission.

Transmission Distance: Up to a couple of hundred meters



Single-mode fiber has a much smaller core than multimode through which only one mode will propagate. The small core and single light-wave virtually eliminate any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fiber cable type

Transmission Distance: Up to thousands of km

Transceivers

Form factors

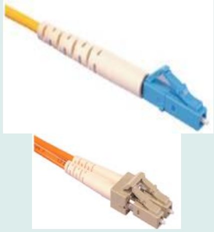
SFP/SFP+

QSFP28/QSFP-DD

CFP/CFP2

Connector Types

LC



SC

MTP/MPO

TRX Types

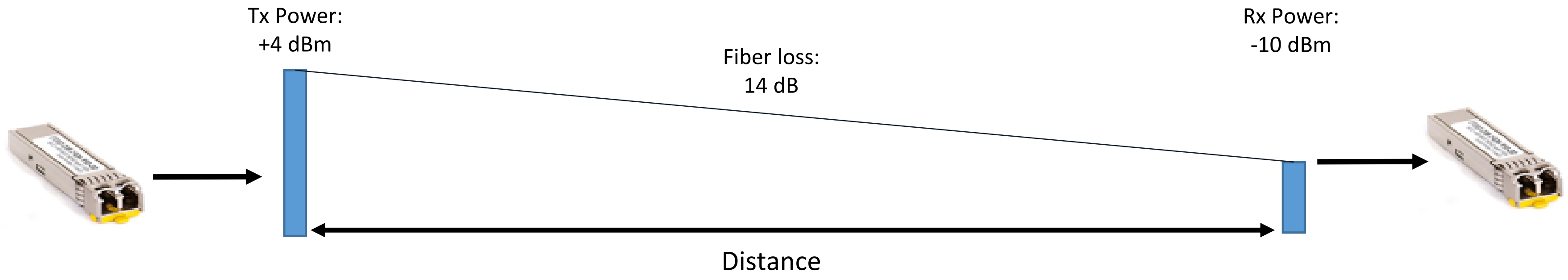
SFP and SFP+

SR	"short range"	850 nm	300 m
LR	“long reach”	1310 nm	10 km
LRM	”Long Reach Multimode”	1310 nm	220 m
ER	"extended reach"	1550 nm	40 km
ZR	"Longer extended reach"	1550 nm	80 km

QSFP28 and QSFP-DD

SR4	850 nm	300 m	MPO
SWDM4	850 nm	150 m	LC
CWDM4	1310 nm	2 km	LC
PSM4	1310 nm	2 km	MPO
LR4	1310 nm	10 km	LC
ER4	1310 nm	40 km	LC

dB for loss and dBm for powerlevels



The unit's dB and dBm stands for decibel and decibel milliwatt, respectively.

Absolute Power in dBm:

The optical power is measured in milliwatts (mW), but for convenience, we use the dBm units, where:

-20 dBm	= 0.01 mW
-10 dBm	= 0.1 mW
0 dBm	= 1 mW
10 dBm	= 10 mW
20 dBm	= 100 mW

Power Difference in dB:

The dB value is the difference between two dBm values.

Examples:

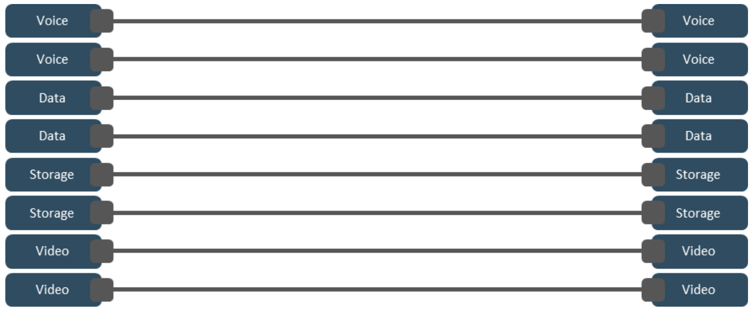
50% of the power equals a loss of 3 dB, or a change of –3 dB

10% of the power equals a loss of 10 dB, or a change of –10 dB

1% of the power equals a loss of 20 dB, or a change of – 20 dB

smartoptics

What is WDM?



Individual dark fibers per service

Multiple fibers required (wasteful and high Opex)

Single channel (grey) transceivers

WDM

Multiple services transported together on one dark fiber

Wavelength specific (colored) transceivers connect to a multiplexer

Single dark fiber connection required instead of multiple

Maximizes fiber utilization and significantly reduces opex

Huge amounts of data can be synchronously connected between sites

Different Wavelength Divisioning Technology's

Coarse Wavelength Division Multiplexing

Up to **18** wavelength channels

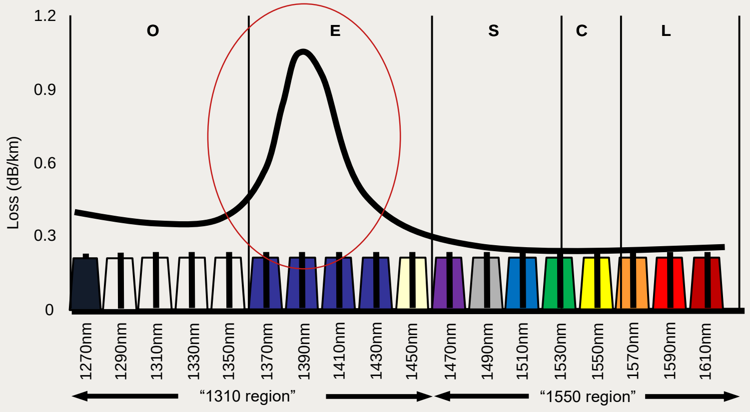
20nm channel spacing

70km, unamplified only technology

Water Peak limits usable range

Sweet spot: **10/1GE and 4/2/1GFC**

Historically was lower in cost, large install base



Dense Wavelength Division Multiplexing

Up to **96** wavelength channels

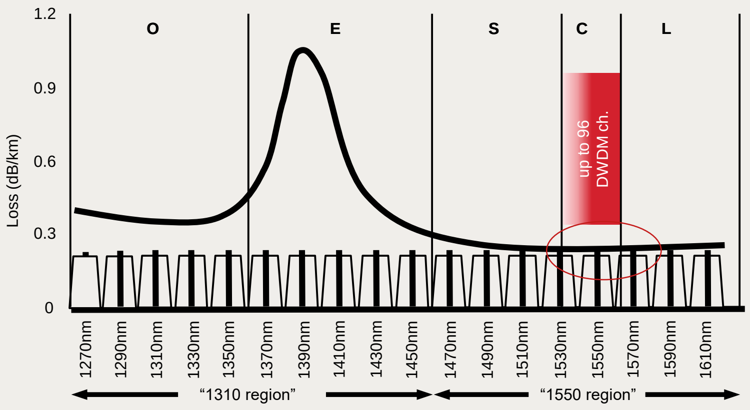
0.8nm channel spacing

80km unamplified, **200km** amplified, 1000km+ with OLA

Flat region avoids Water Peak and is ideal for amplification

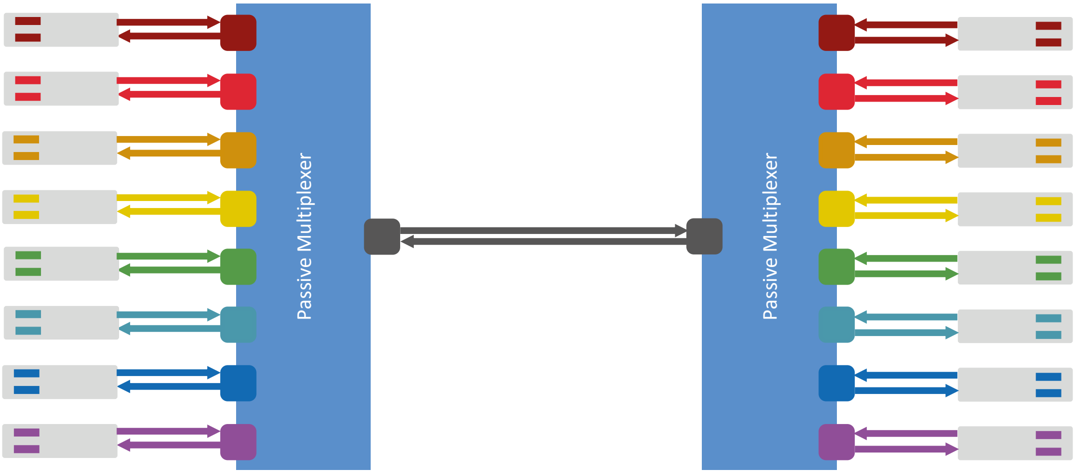
Sweet spot: **400/100/40/10GE and 32/16/8G FC**

Technology of choice for green field installations

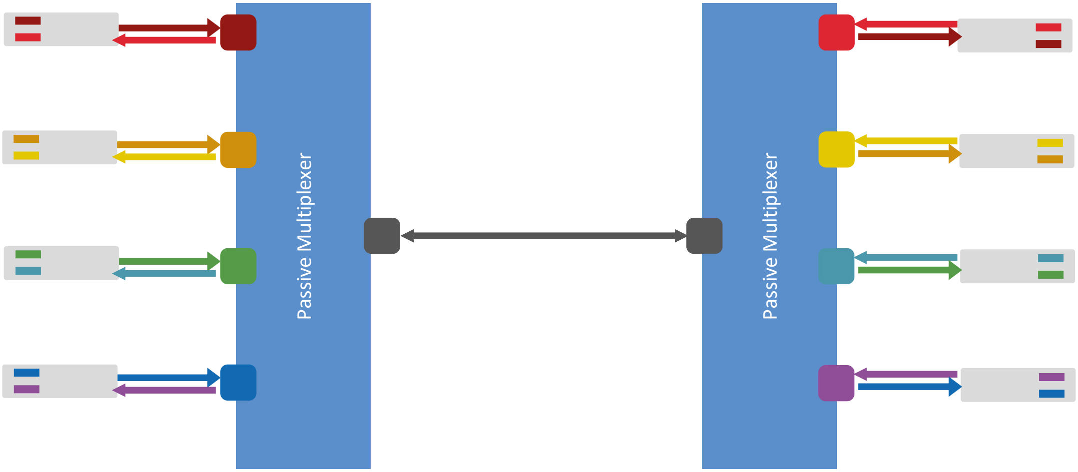


smartoptics

Fiber pair vs Single fiber transmission



Fiber pair
Transmitting and receiving data on two fiber strands
1 used for transmitting
1 used for receiving



Single fiber
1 line fiber used for transmitting and receiving
2 wavelengths used to create 1 ch
Tx is narrow band xWDM signal
Rx is wideband

Transmission Challenges

Effects of Fiber Loss

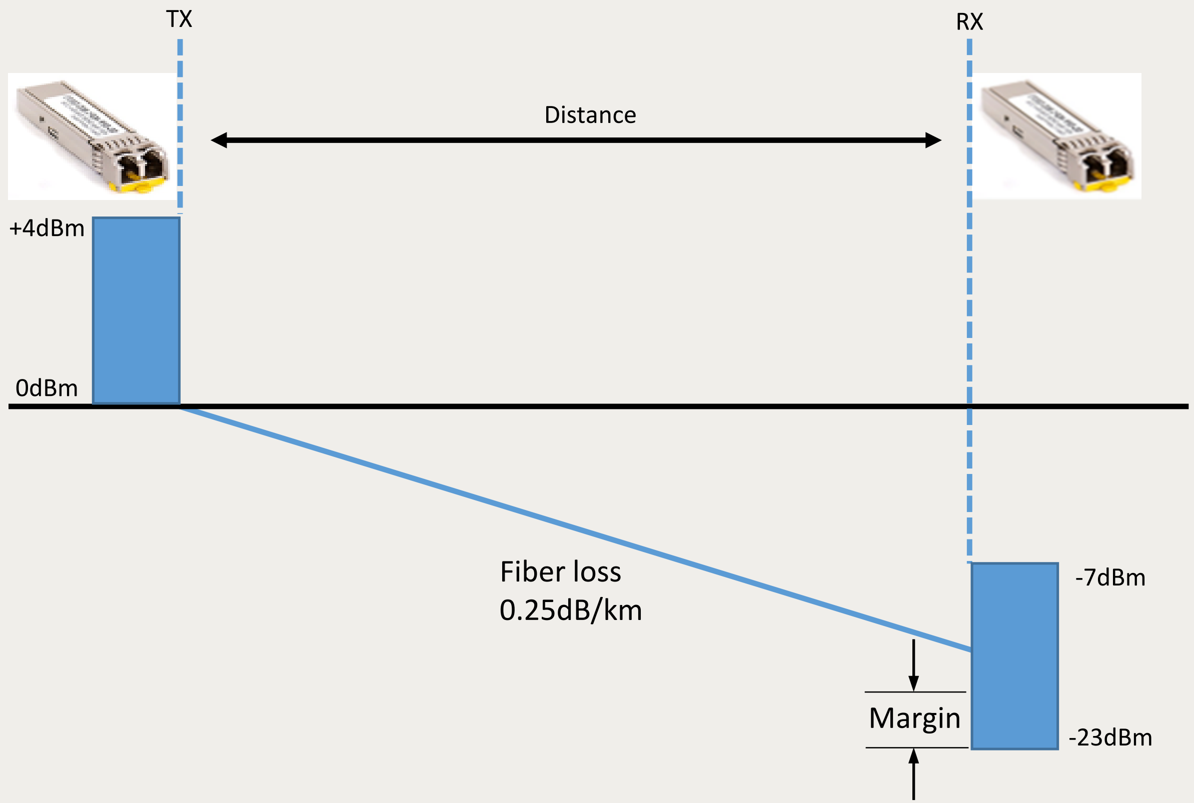
Example

Fiber data

- Fiber distance: 80km
- Fiber Loss: 0.25dB/km
- Fiber type: G.652

Transceiver specifications

- Transceiver launch power
- Max +4 dBm Min +0dBm
- Receive sensitivity
- Saturation -7dBm Min -23dBm



Calculate Margin:

Total Fiber Loss: 0.25 * 80 = 20dB

Transmission budget: 0 – (-23) = 23dB

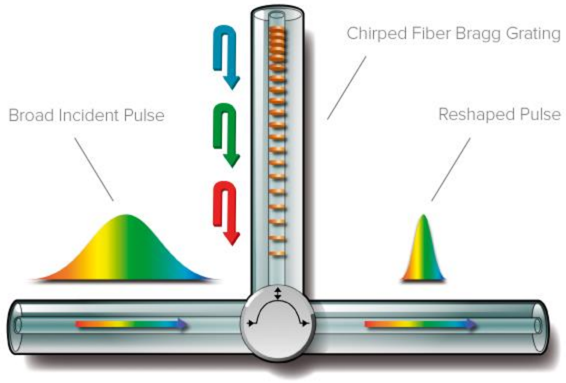
Transmission Margin: 23 – 20 = 3 dB

Chromatic dispersion

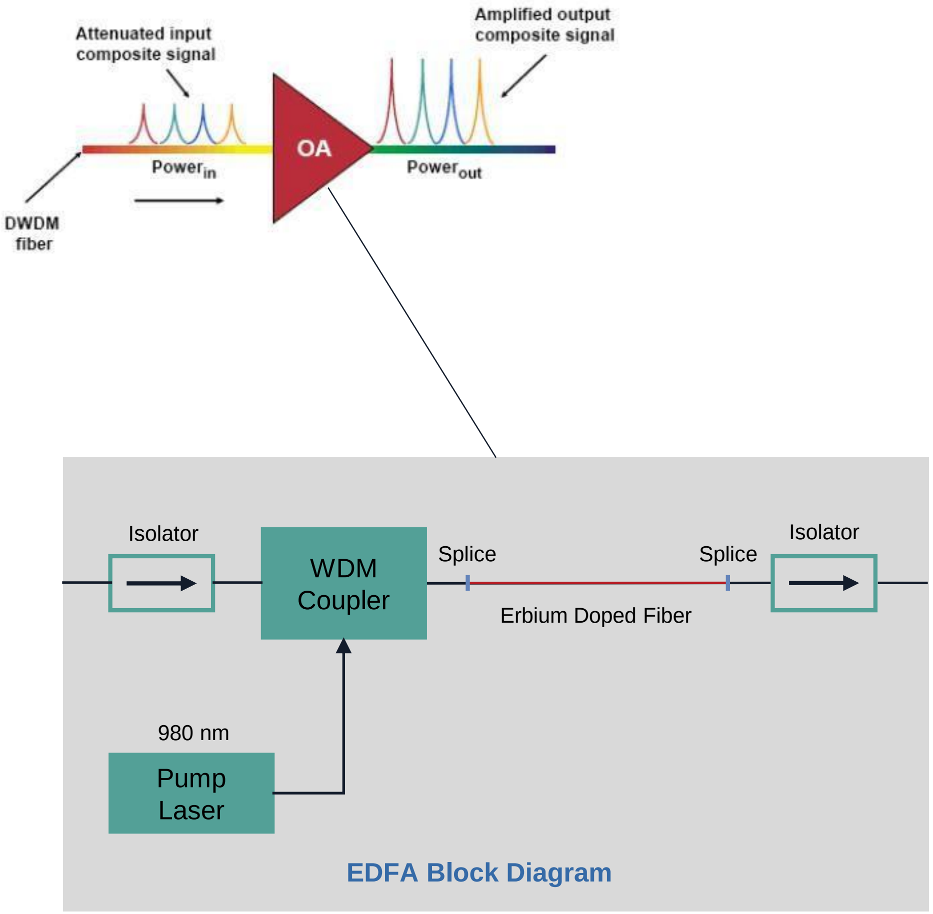
The refractive index of fiber has a wavelength dependent factor; wavelengths are not travelling at the same speed (the higher frequencies travel faster than the lower frequencies)

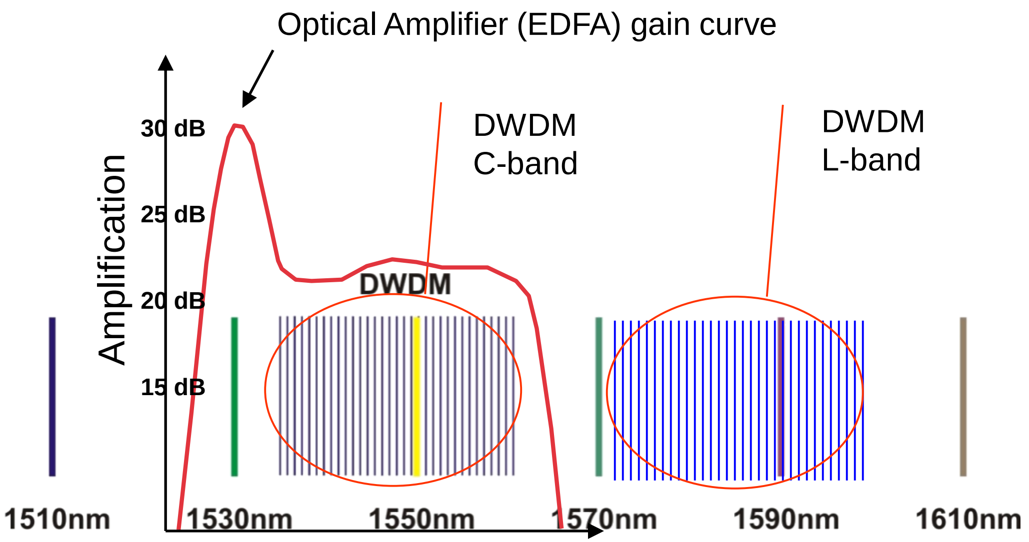
Effects of chromatic dispersion can be compensated in the following ways:

- Electrical regeneration
- Dispersion compensation modules (DCM)
- Use of dispersion shifted fibers
- Coherent DWDM technology with special signal processors



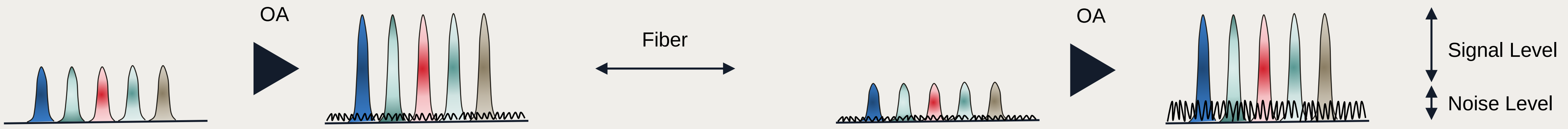
Optical Amplifier





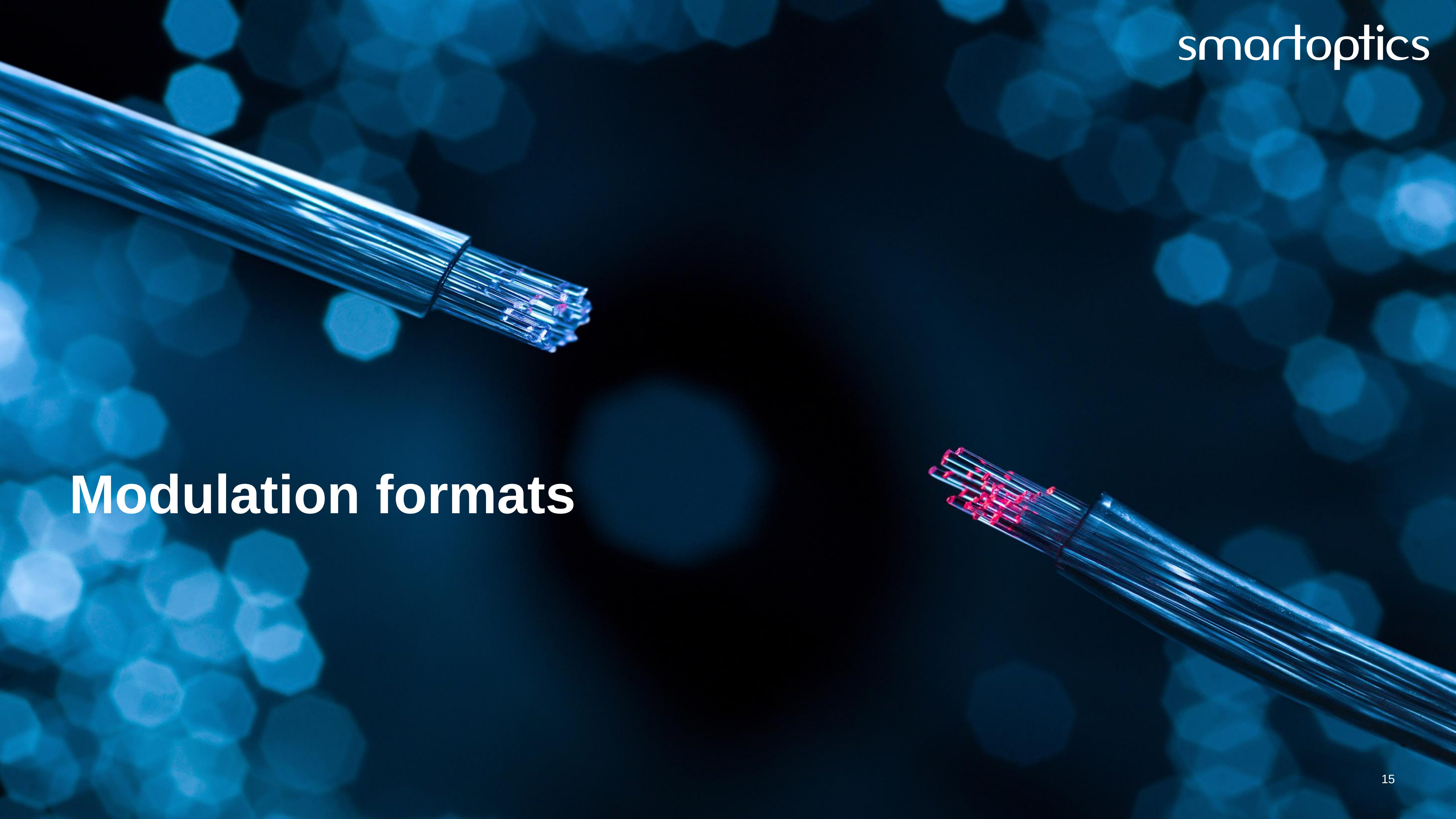
OSNR

Optical Signal-to-Noise Ratio



How to calculate OSNR

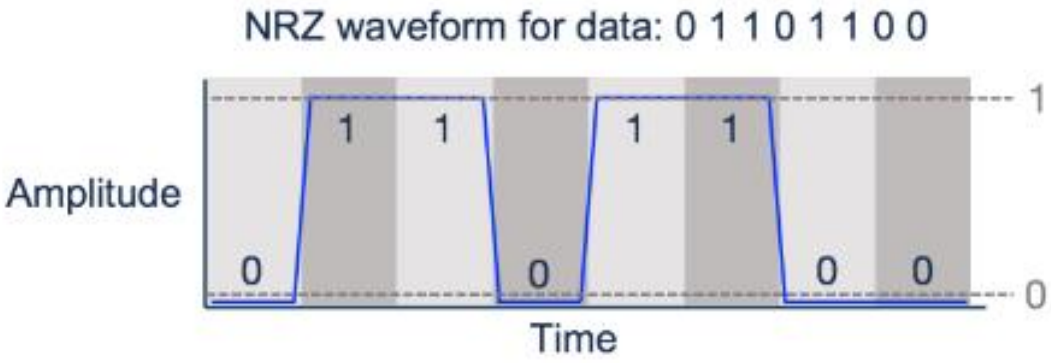
$$OSNR(dB)= 10lg * (P_{signal\ (mW)} / P_{noise\ (nW)}) = P_{signal\ (dBm)} - P_{noise\ (dBm)}$$

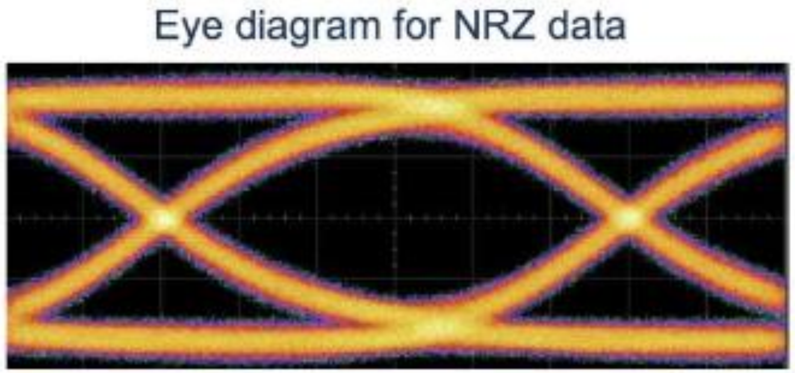


Modulation formats

NRZ Modulation

None Return to Zero (NRZ) Modulation

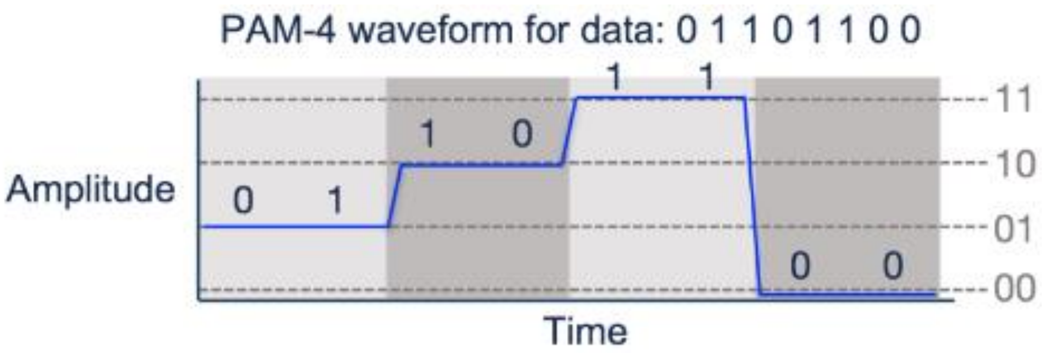


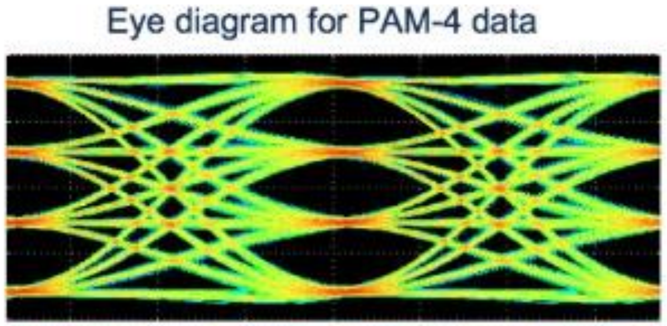


Example: 10G DWDM Transceiver

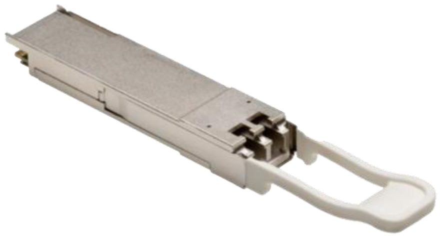
PAM4 Modulation

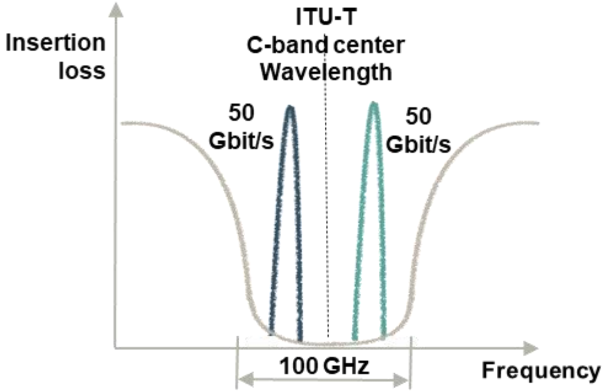
Pulse Amplitude Modulation, 4-levels (PAM4)





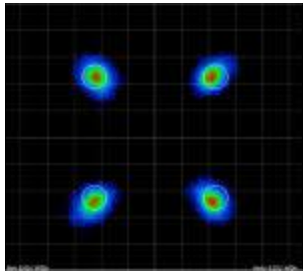
Example of a 100G PAM4 DWDM



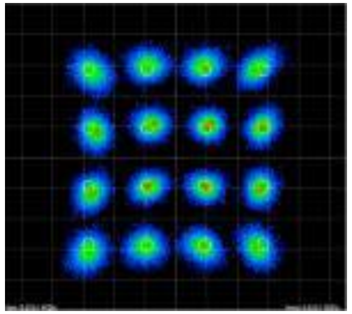


Coherent modulation

Quadrature Phase Shift Keying(QPSK)



16 Levels Quadruple Amplitude Modulation (16QAM)

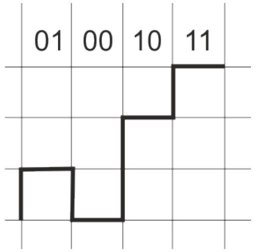


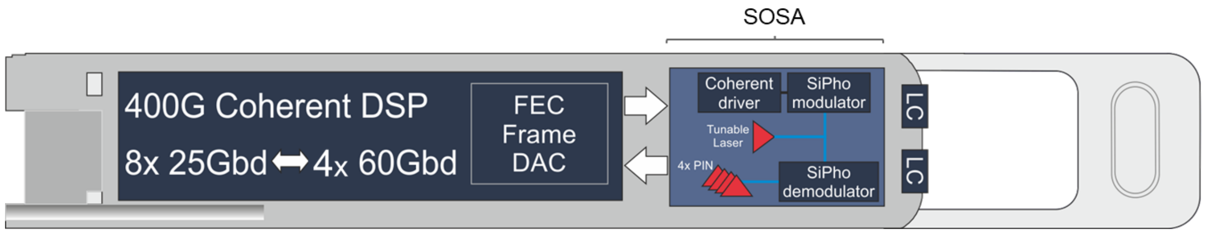
Example of a 400ZR Transceiver

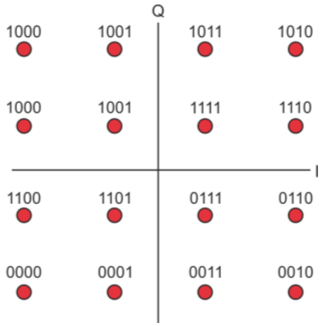
Electrical Signal (8xPAM4)

Optical Signal (16QAM)

P ulse
A mplitude
M odulation
4 Levels







DSP: Digital Signaling Processor

SOSA: Silicon Optical Sub-Assembly

smartoptics

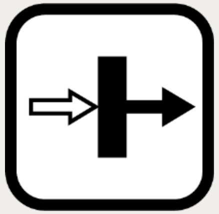
Optical Solutions

Building Blocks for Optical Solutions

Mux/Demux

OCM

Optical Channel Monitor



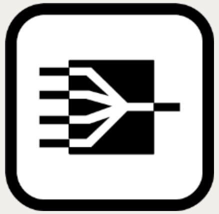
Transponder

WSS/
EQ

Wavelength Selective Switch
Equalizer

DCM

Dispersion Compensation Module



Muxponder

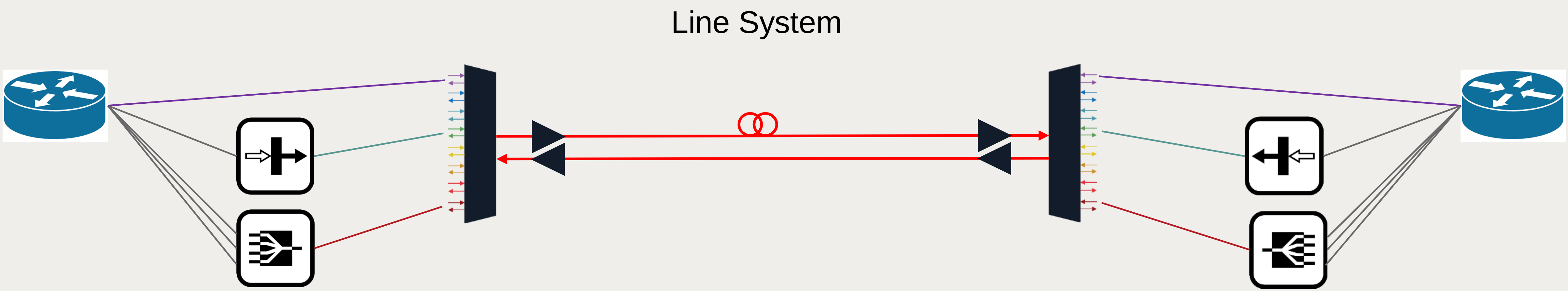
Optical Amplifier

VOA

Variable Optical Attenuator

OSC Filter

How to combined those components

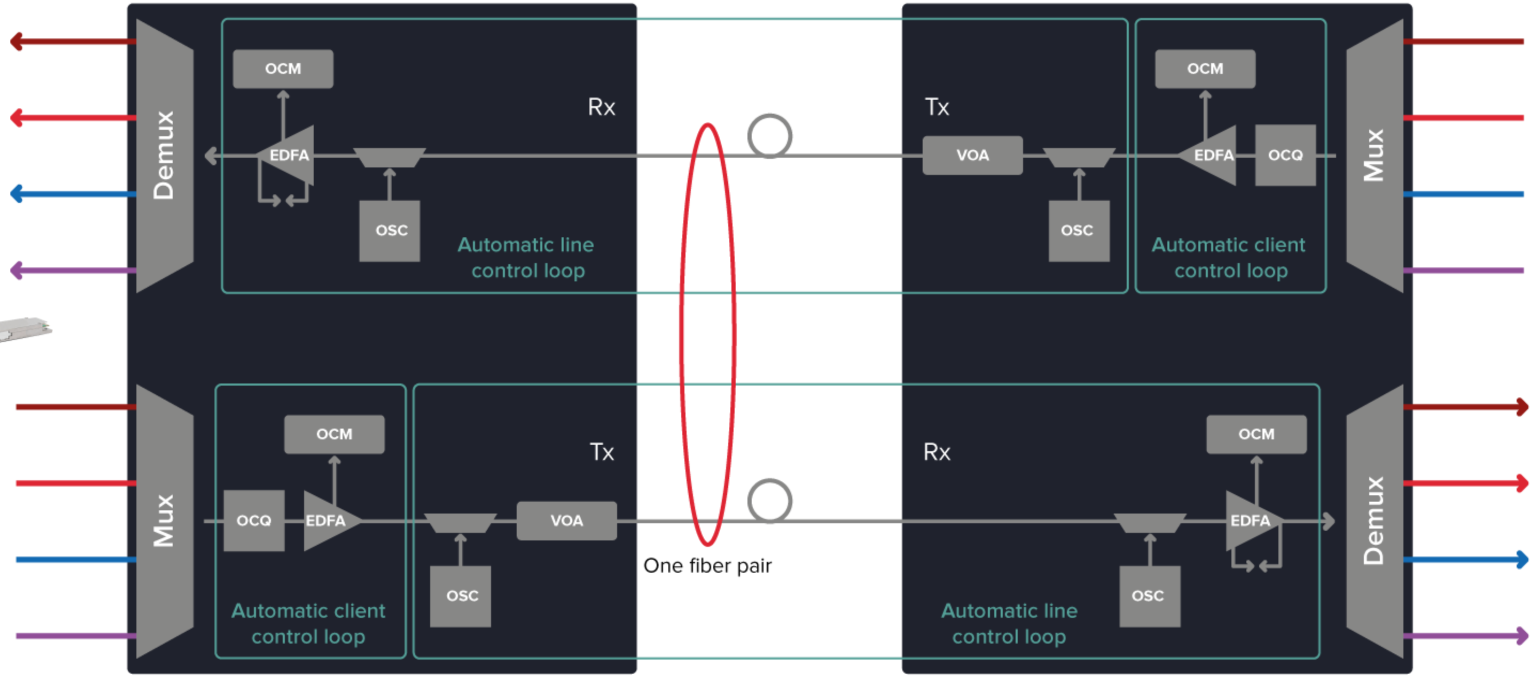


smartoptics

Optical System Description (DCP-M)

- Client control loop
  - Automatic protocol detection
  - Automatic power level measurement
  - Automatic power level regulation

- Line control loop
  - Automatic measure of fiber length
  - Automatic setting of dispersion compensation
  - Automatic power level regulation

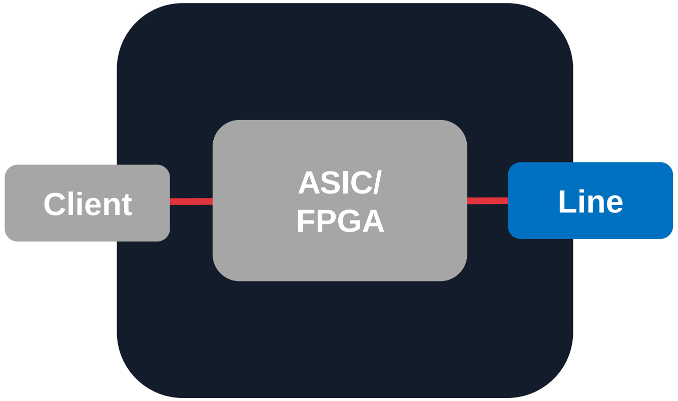


Transponder

Transponder: A transponder converts one client signal into one line signal

10/40/100 GbE

16/32G FC



OTU2

OTU2e

OTU4

ASIC / FPGA

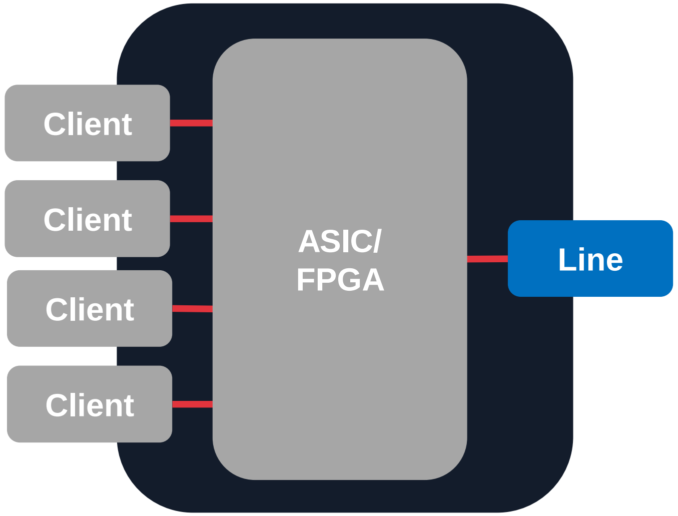
Converts Client Signal Format into a Line Signal, typically OTN

Muxponder

Muxponder: A muxponder converts several client signals into one line signal

10/40/100 GbE

16/32G FC



OTU2

OTU2e

OTU4

ASIC / FPGA

Preforms TDM Multiplexing

Converts Client Signal Format into a Line Signal, typically OTN

Thank you