

Extending 100Gbit/s Ethernet

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Agenda

- AMS-IX
- 100Gbit/s technology
- Problem statement
- Optical Amplifier development
- Metro DWDM equipment
- Production results



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- **AMS-IX**
- 100Gbit/s technology
- Problem statement
- Optical Amplification
- Metro DWDM equipment
- Production results



AMS-IX

- Amsterdam Internet Exchange
 - Not for profit organization.
 - 516 Networks (ASes).
 - 1857Gbit/s peak
 - 911Gbit/s average over the last 16 months
 - 11 Operational sites.
 - Equinix AM3 almost ready.
 - 24 x 100Gbit/s backbone links.

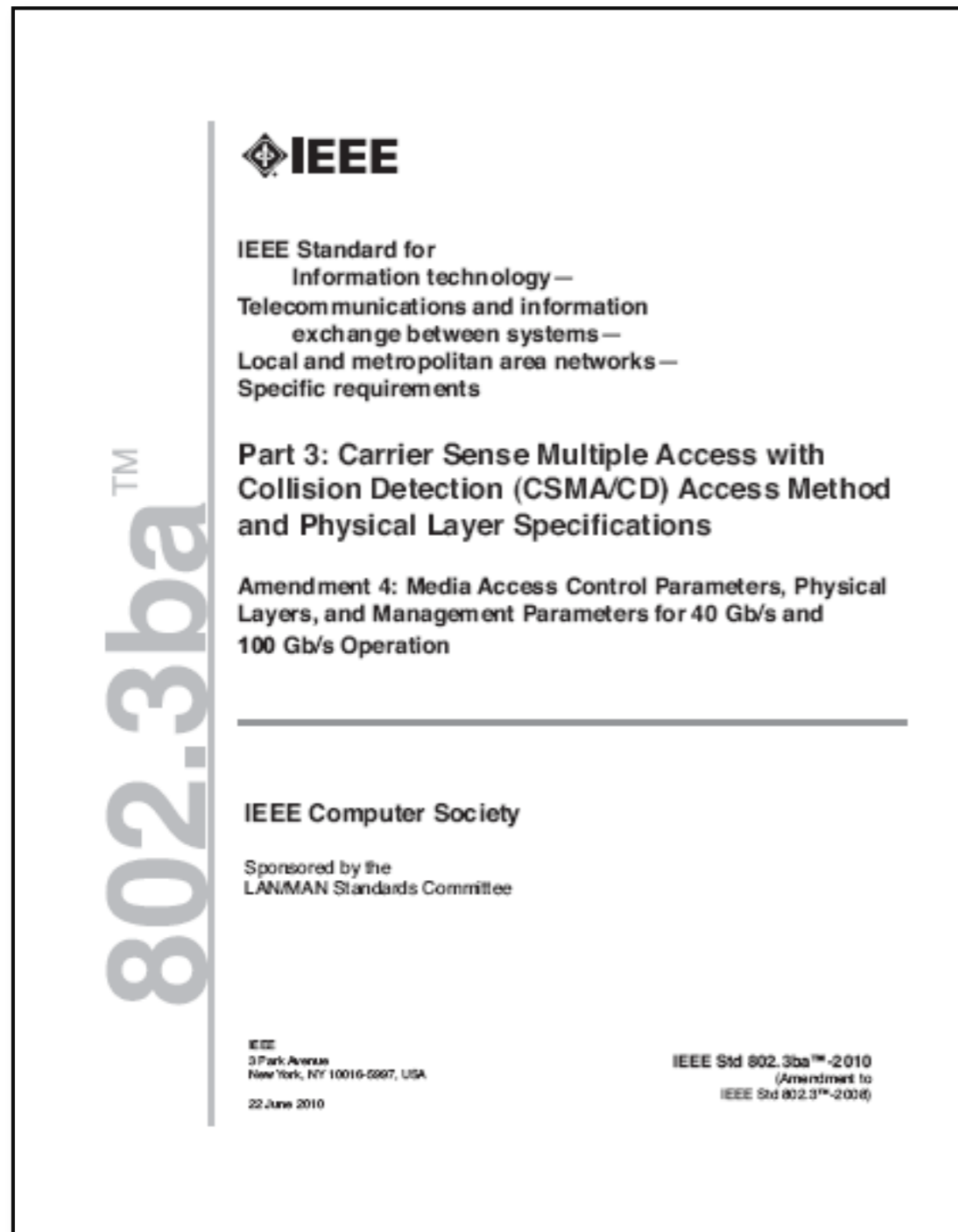


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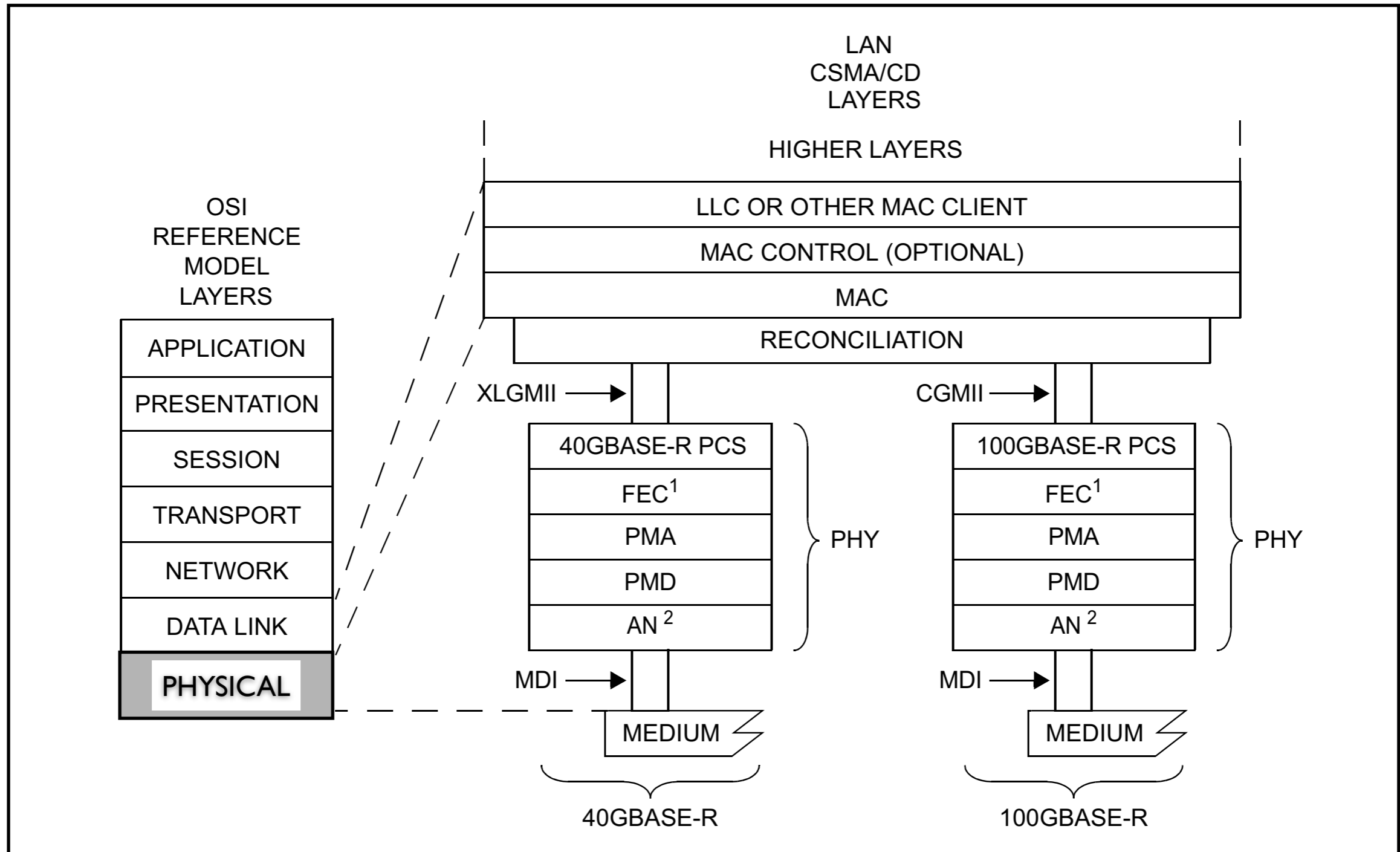


IEEE 802.3ba

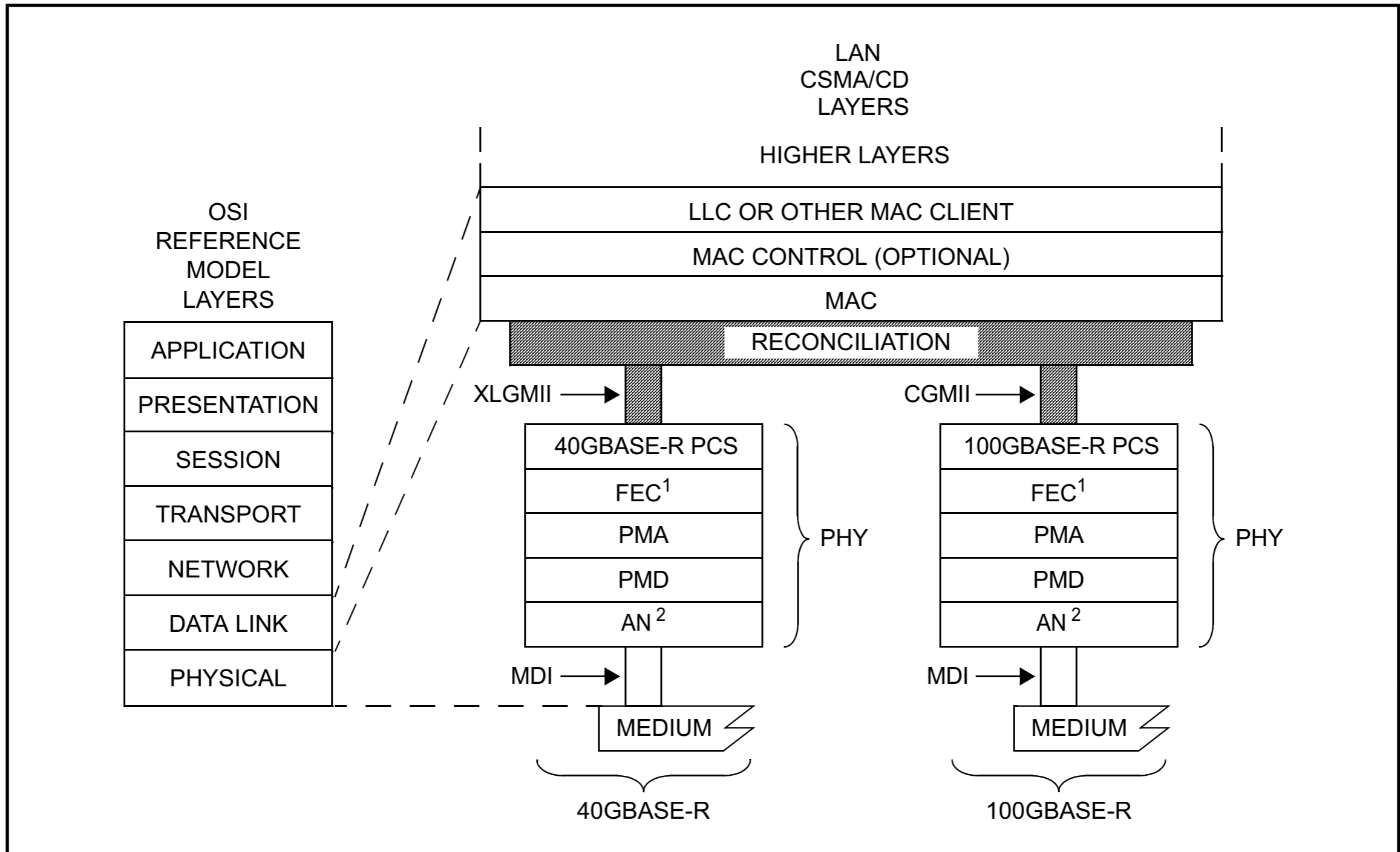


- June 17, 2010
 - IEEE 802.3ba was approved
 - 40GE / 100GE
- 100G
 - 100GBASE-SR10 (< 150m, MMF)
 - 100GBASE-LR4 (< 10km, SMF)
 - 100GBASE-ER4 (< 40km, SMF)

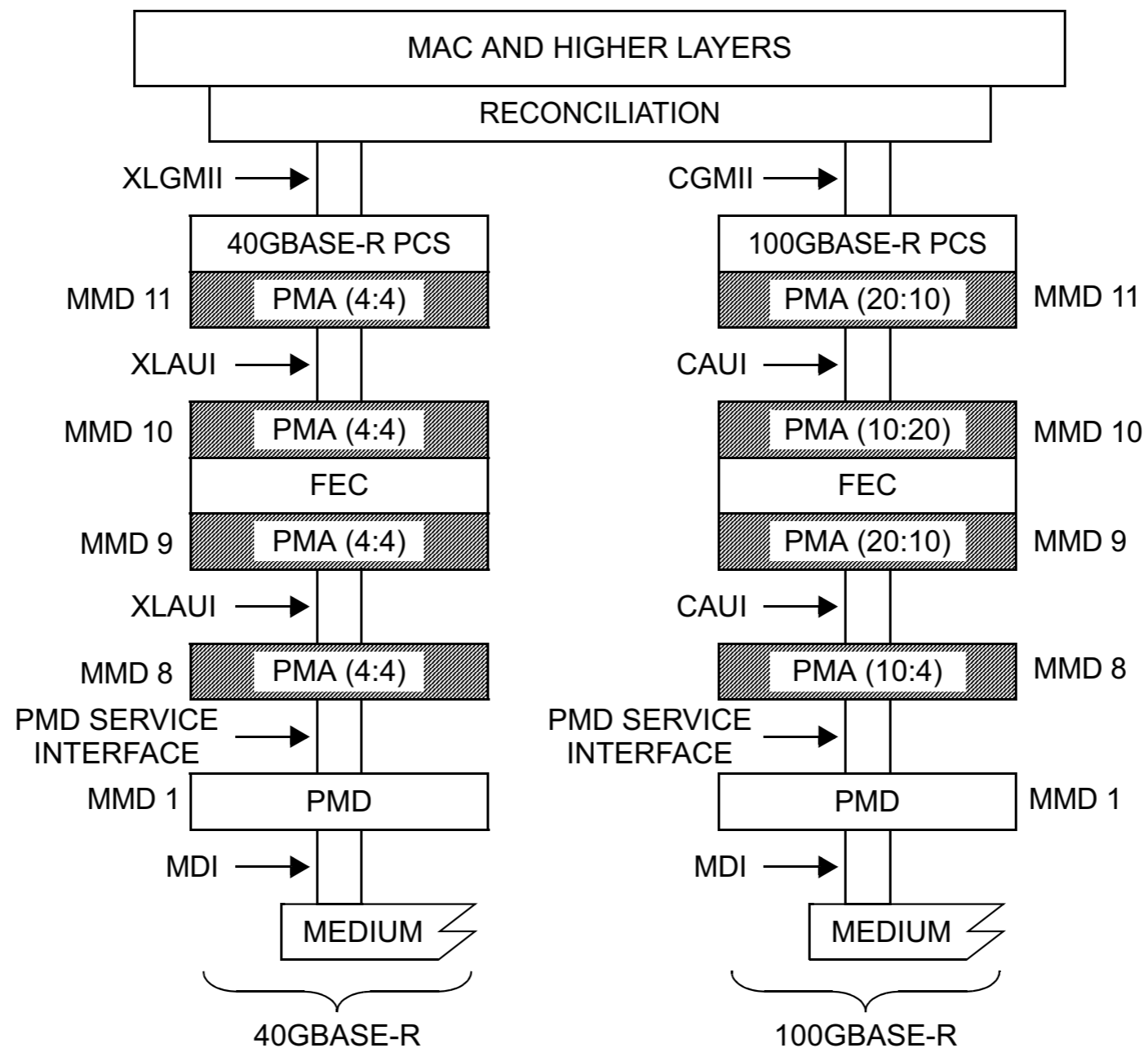
IEEE 802.3ba



IEEE 802.3ba

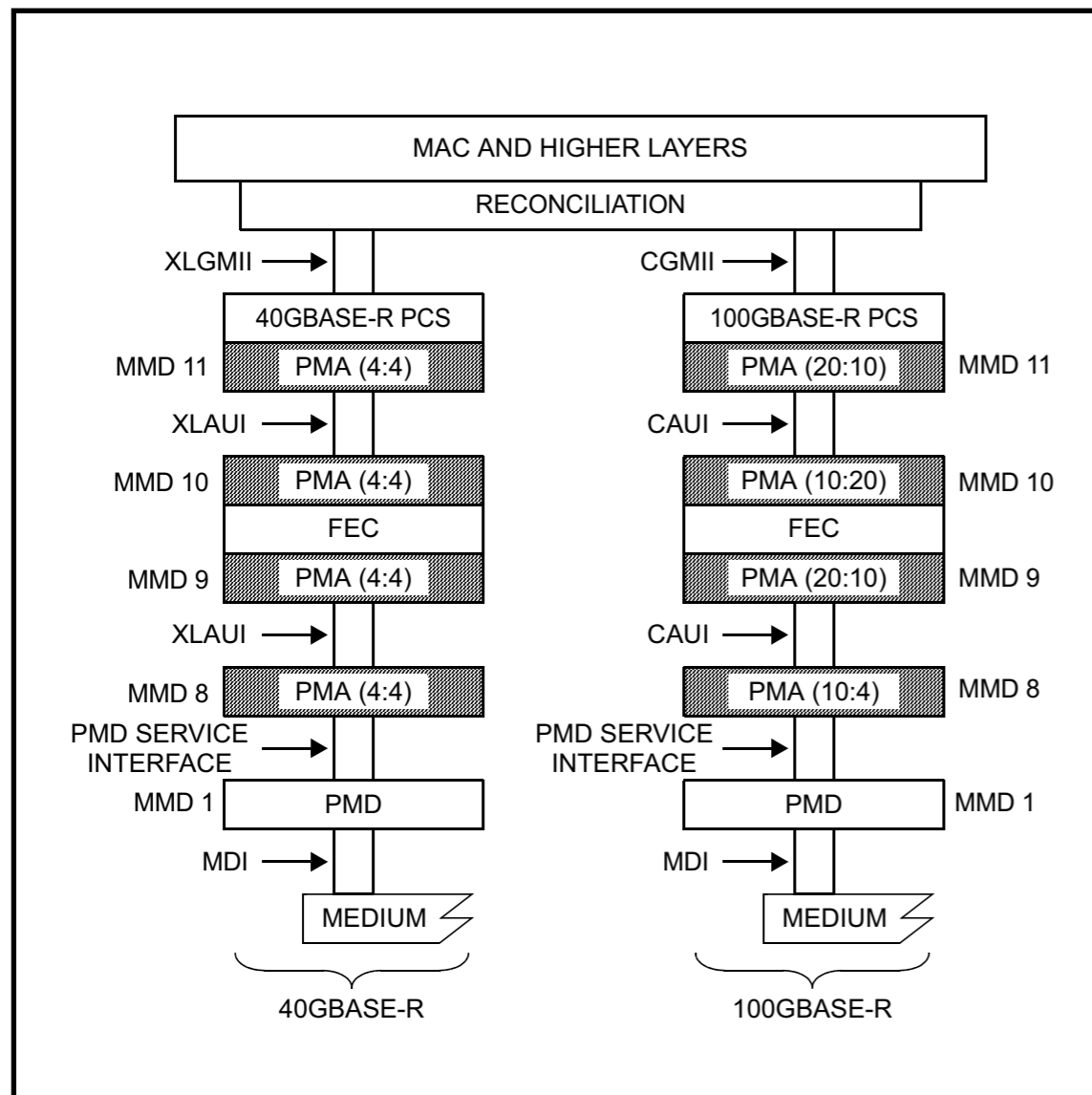


IEEE 802.3ba

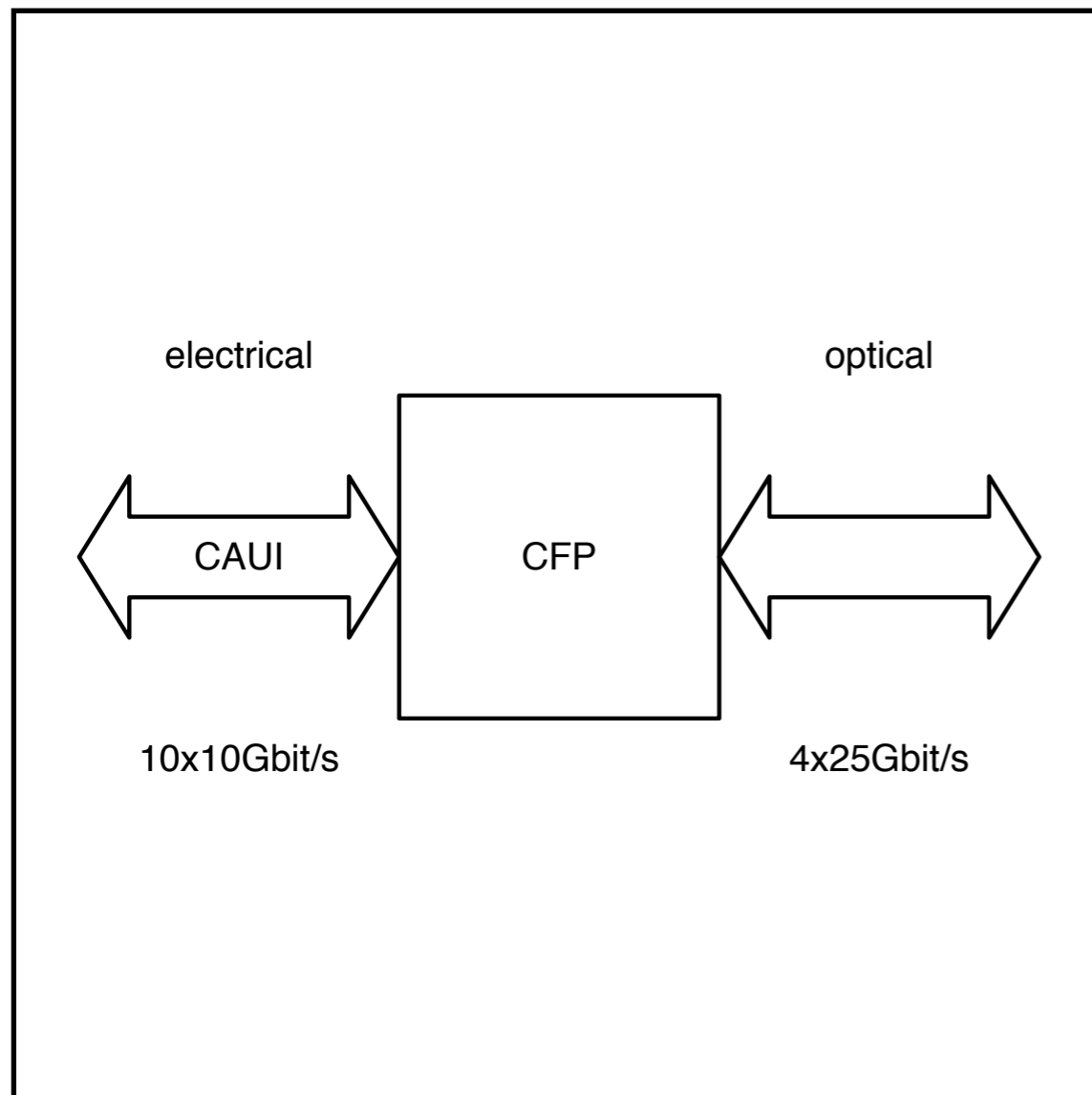


IEEE 802.3ba

- Physical Medium Attachment
- 100Gbit/ Electrical interface
- CAUI (CFP)
 - 10 x 10Gbit/s
- CAUI-4 (CFP-2)
 - 4 x 25Gbit/s
- cPPI-4 (CFP-4)
 - 4 x 25Gbit/s

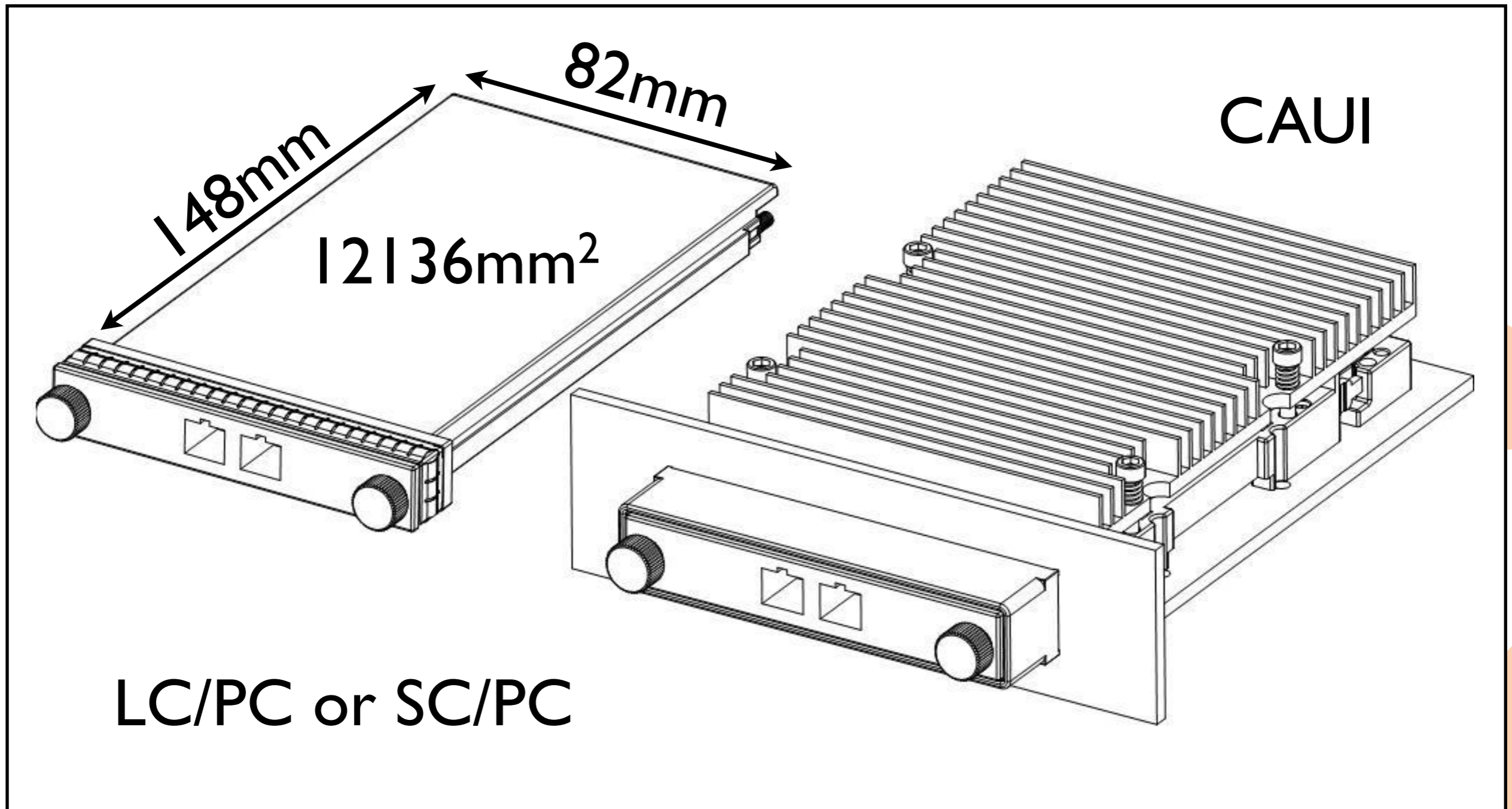


CFP

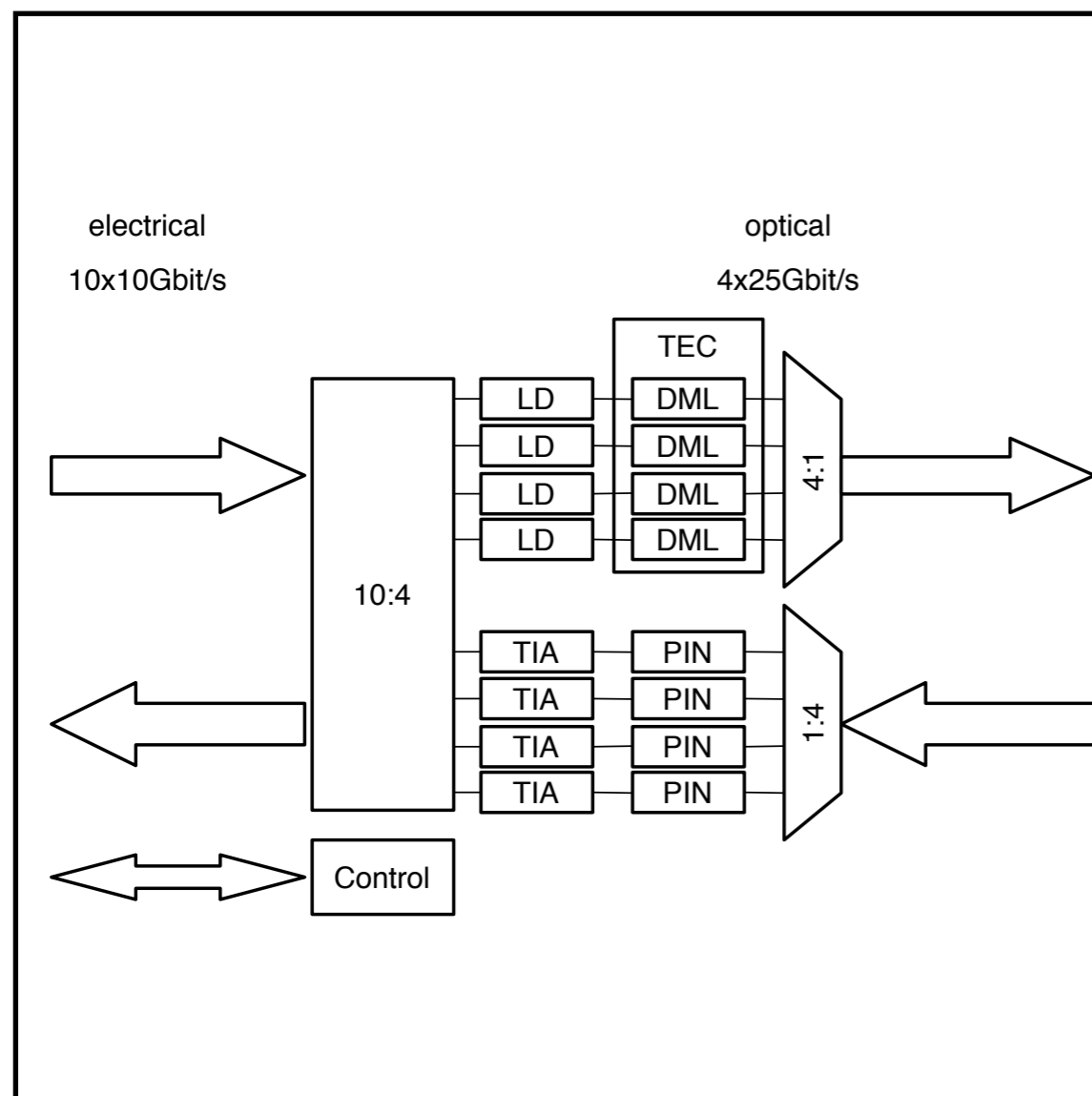


- C Form-factor Pluggable (CFP)
- 100Gbit/ Electrical interface
 - CAUI
 - CFP
 - 10 x 10Gbit/s
- Optical Interface
 - Multi mode 10x10Gbit/s
 - Single mode 4x25Gbit/s

CFP



CFP



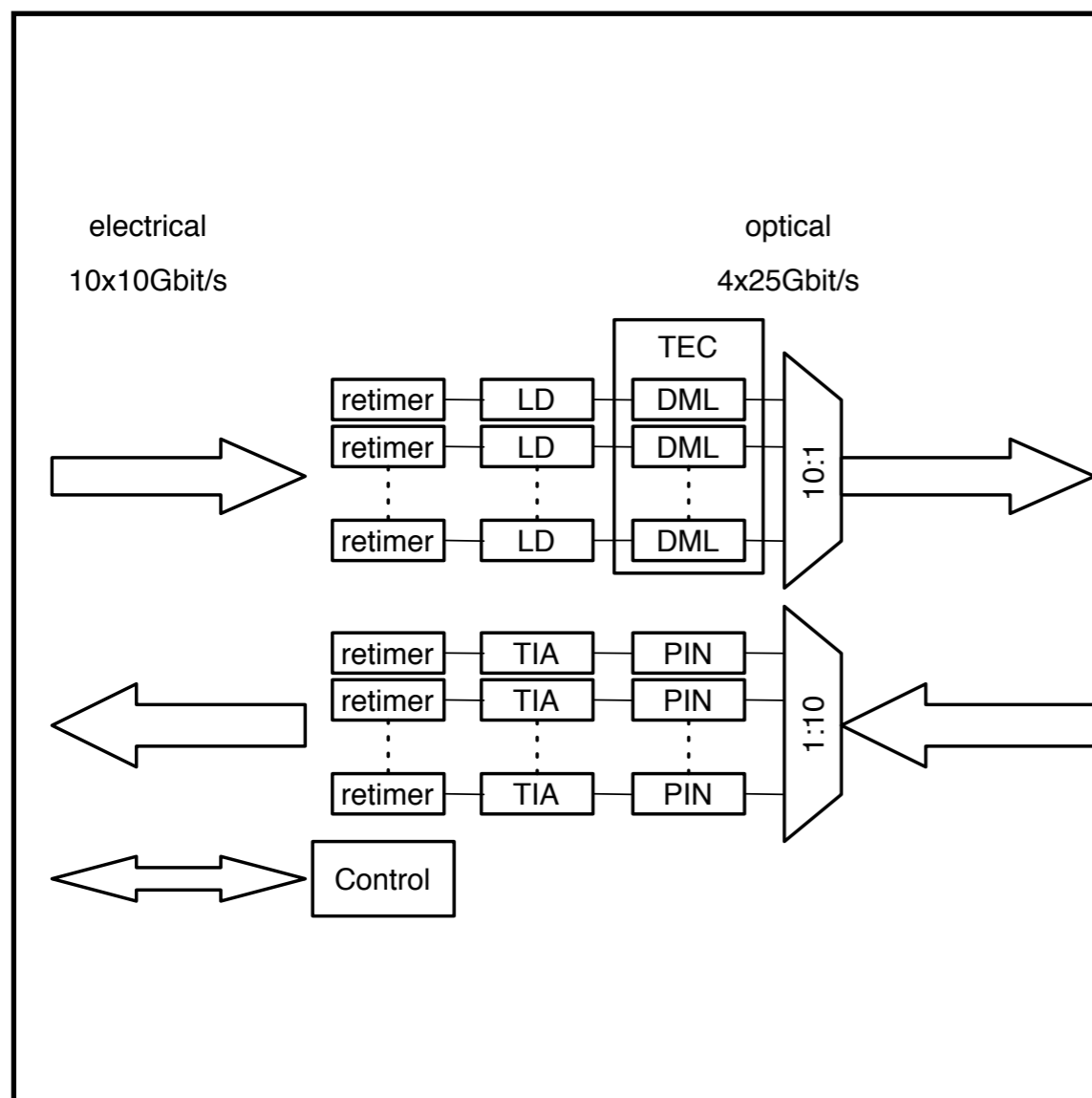
- 10:4 / 4:10 electrical “gearbox”
- 4 transmitters
- 4 receivers
- 4:1 / 1:4 optical muxes
- Control unit
- This is a lot of elements in one transceiver

10x10 MSA



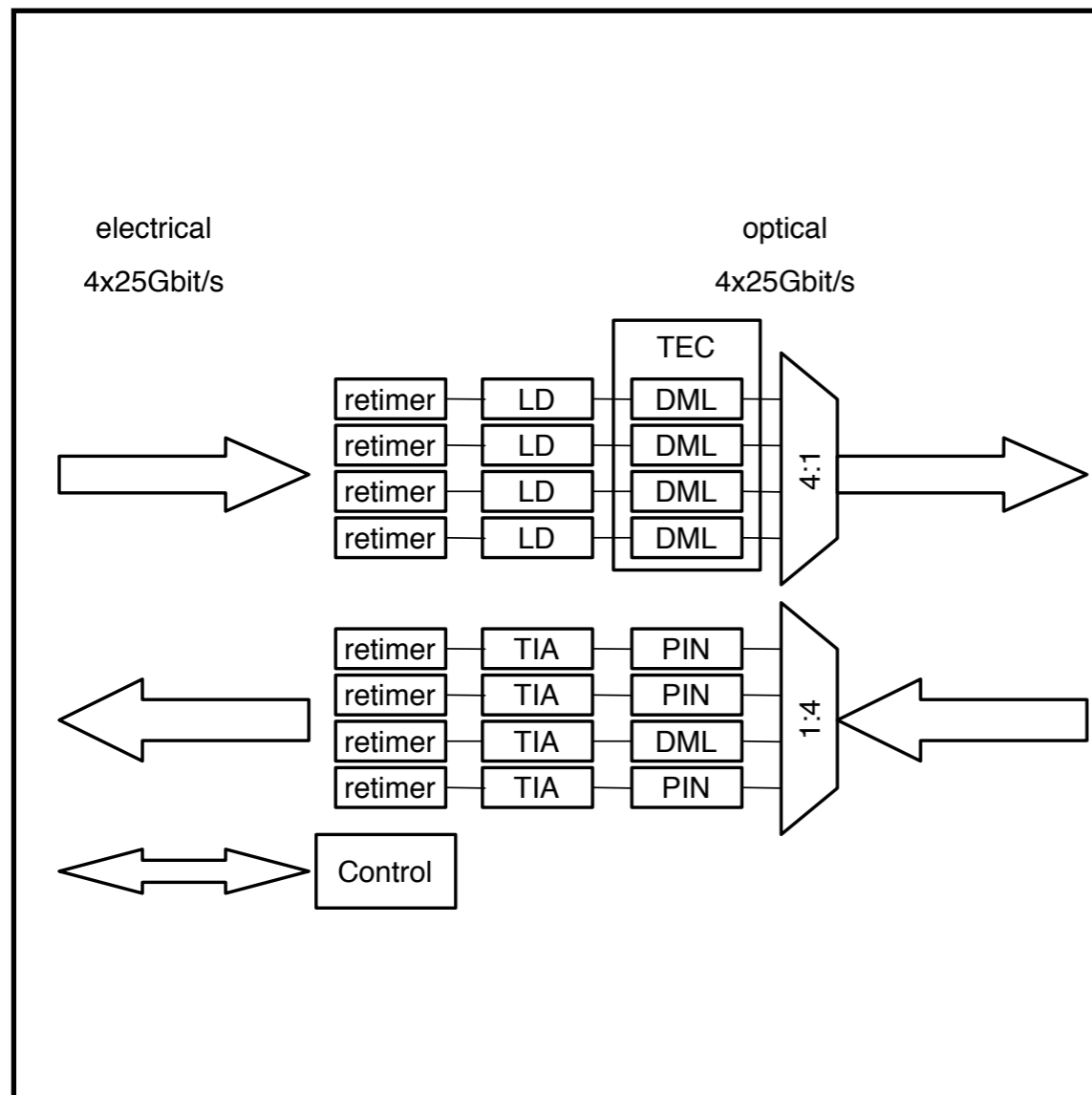
- Outside IEEE initiative
- 26 participants
 - Network operators
 - AMS-IX among others
 - No Cisco, Juniper, Alcatel
 - Works in Juniper though
- Less expensive 100GBASE-LR4 between:
 - 100GBASE-SR10 supports up to 150m (OM4 MMF)
 - 100GBASE-LR4 supports up to 10km (SMF)

10x10 MSA



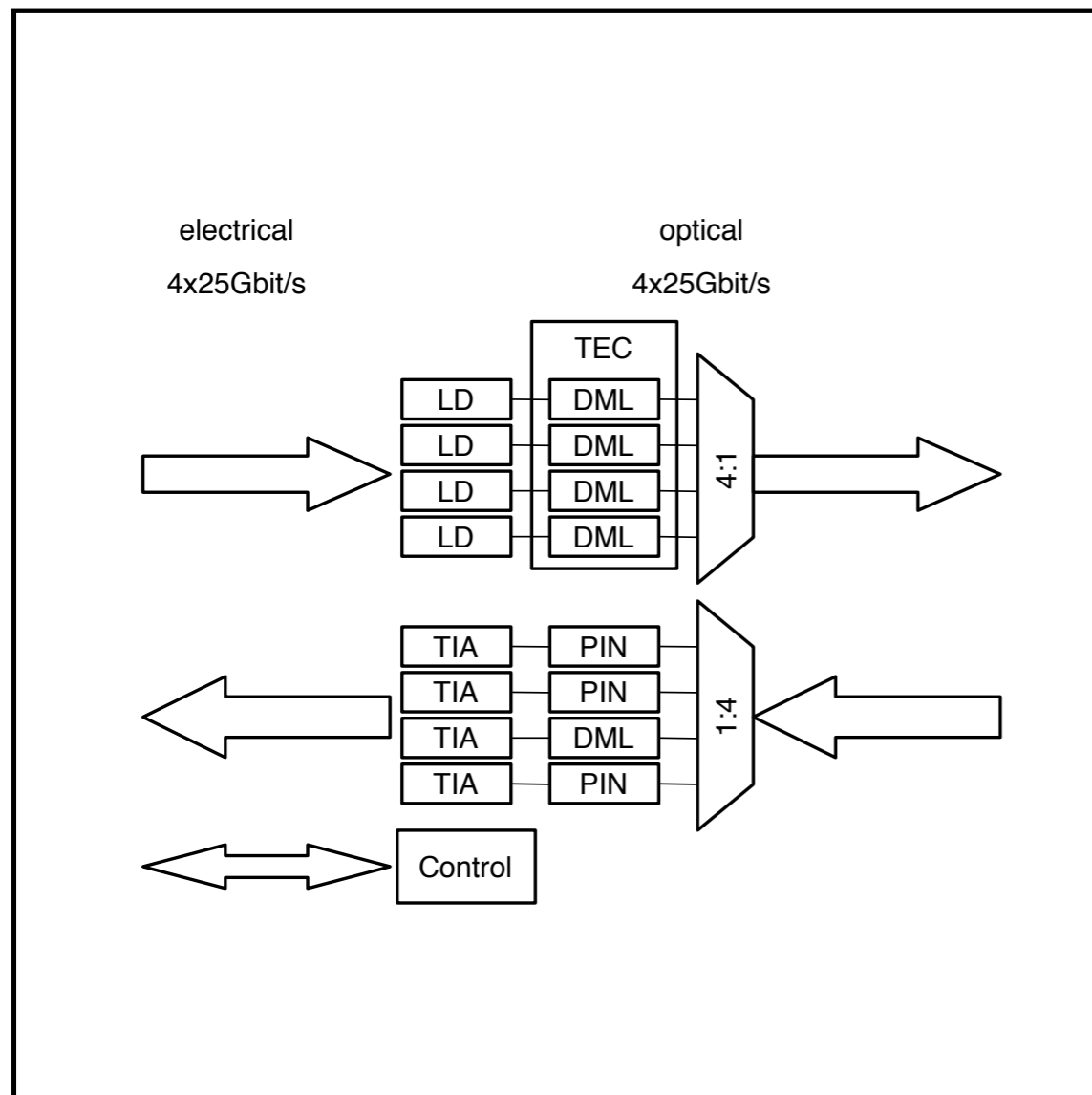
- 10x10Gbit/s electrical and optical
 - 10 Lasers
 - 10 Transceivers
 - 10:1 / 1:10 optical muxes
- No “gearbox”
- Retiming circuits instead
- Considerably cheaper LR-4
- Less power hungry than LR-4

CFP-2 (future)



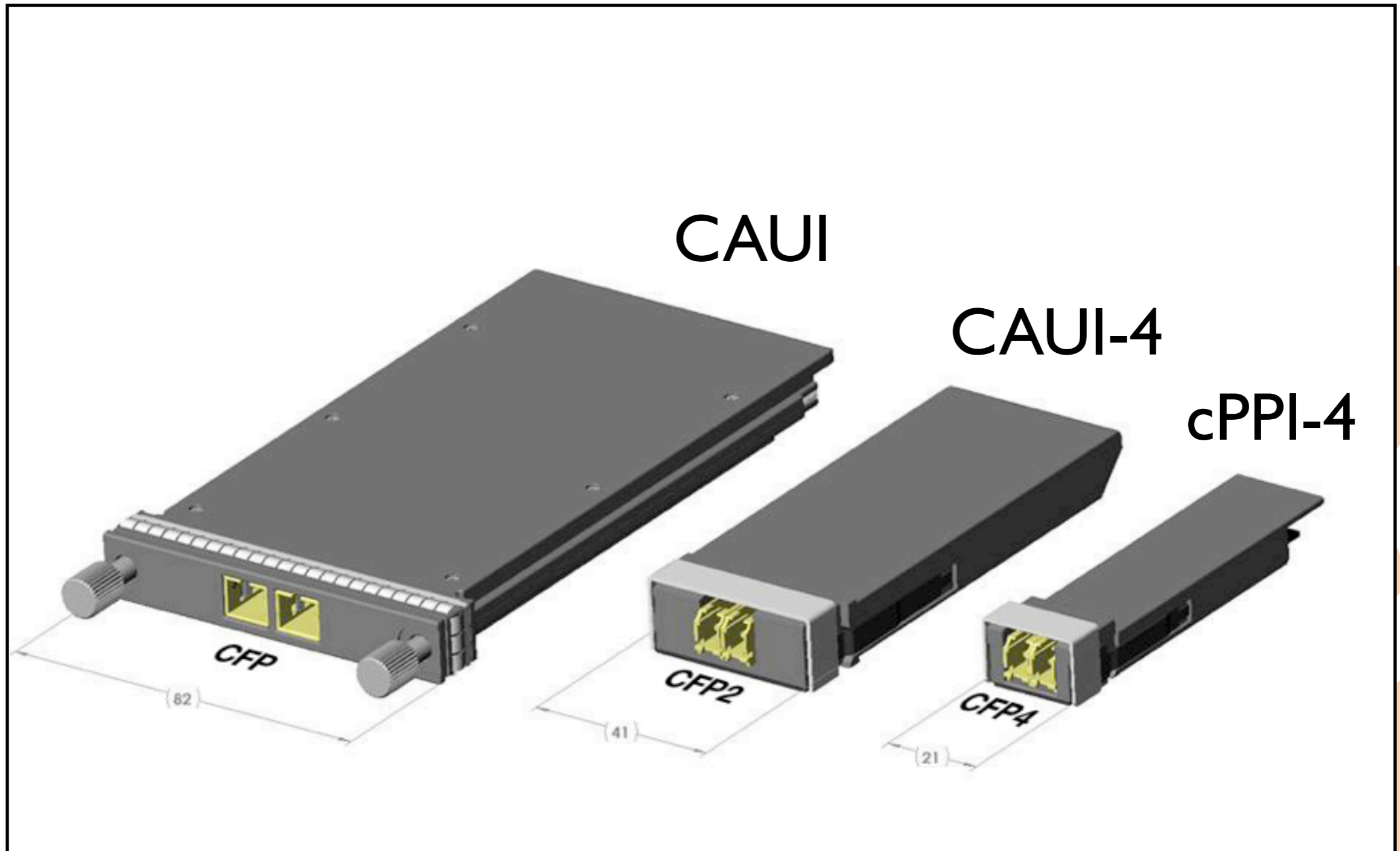
- Smaller modules than CFPs
- 4x25Gbit/s electrical and optical
 - 4 Lasers
 - 4 Transceivers
 - 4:1 / 4:1 optical muxes
- No “gearbox”
- Still Retiming circuits
- Cheaper than CFPs
- Less power hungry than CFPs
- 10x10 MSA would require a gearbox

CFP-4 (future)



- Smaller modules than CFP-2
- 4x25Gbit/s electrical and optical
 - 4 Lasers
 - 4 Transceivers
 - 4:1 / 4:1 optical muxes
- No retiming units
- Require external retiming units.

CFP2, CFP4



Summary

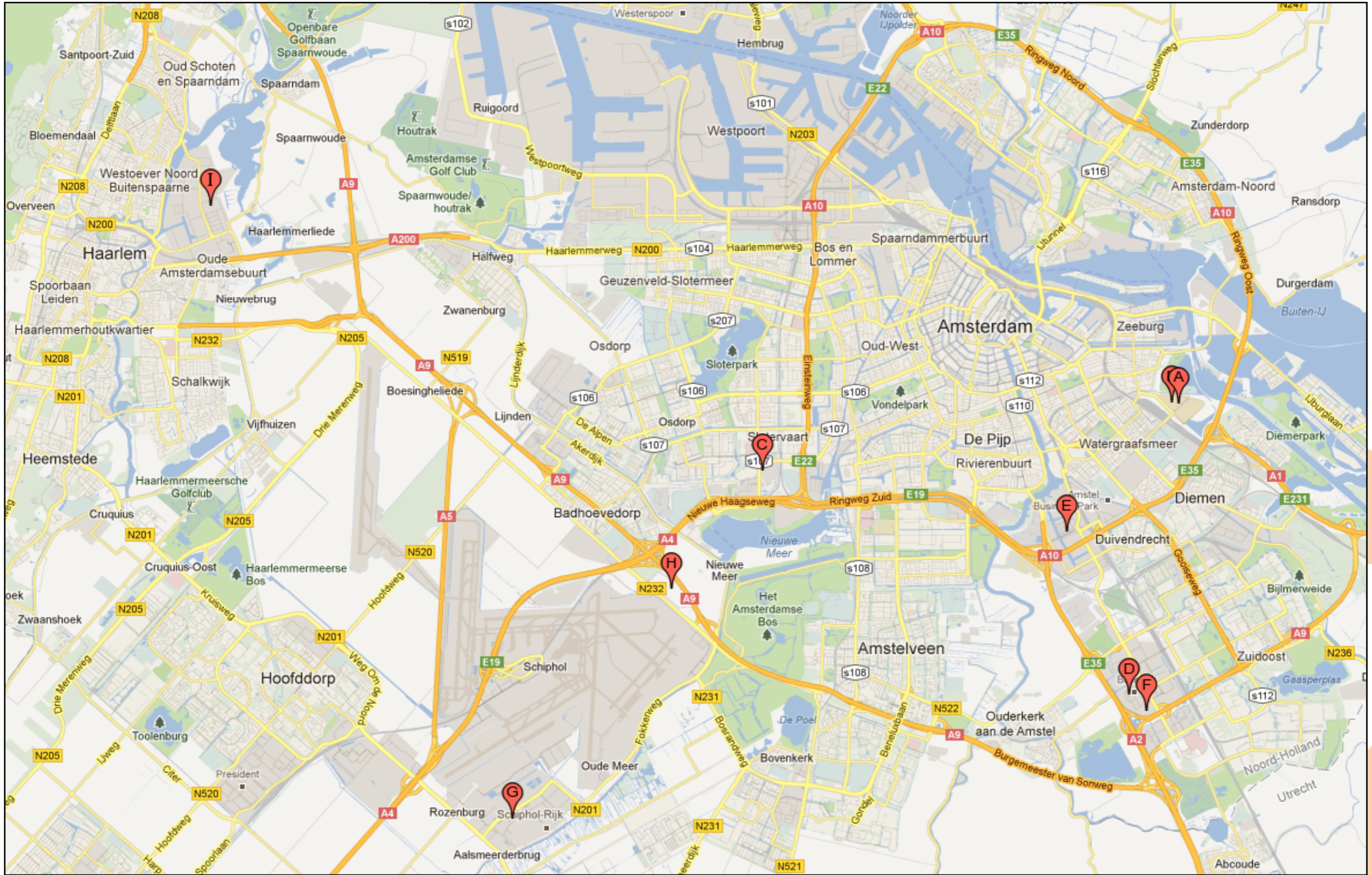
- Transceiver type: CFP
- Electrical Interface
 - 10x10G bit/s
- Optical Interfaces
 - 100GBASE-SR10 (< 150m, MMF)
 - 10x10MSA (<2km, SMF).
 - 100GBASE-LR4 (< 10km, SMF)
 - 100GBASE-ER4 (< 40km, SMF)



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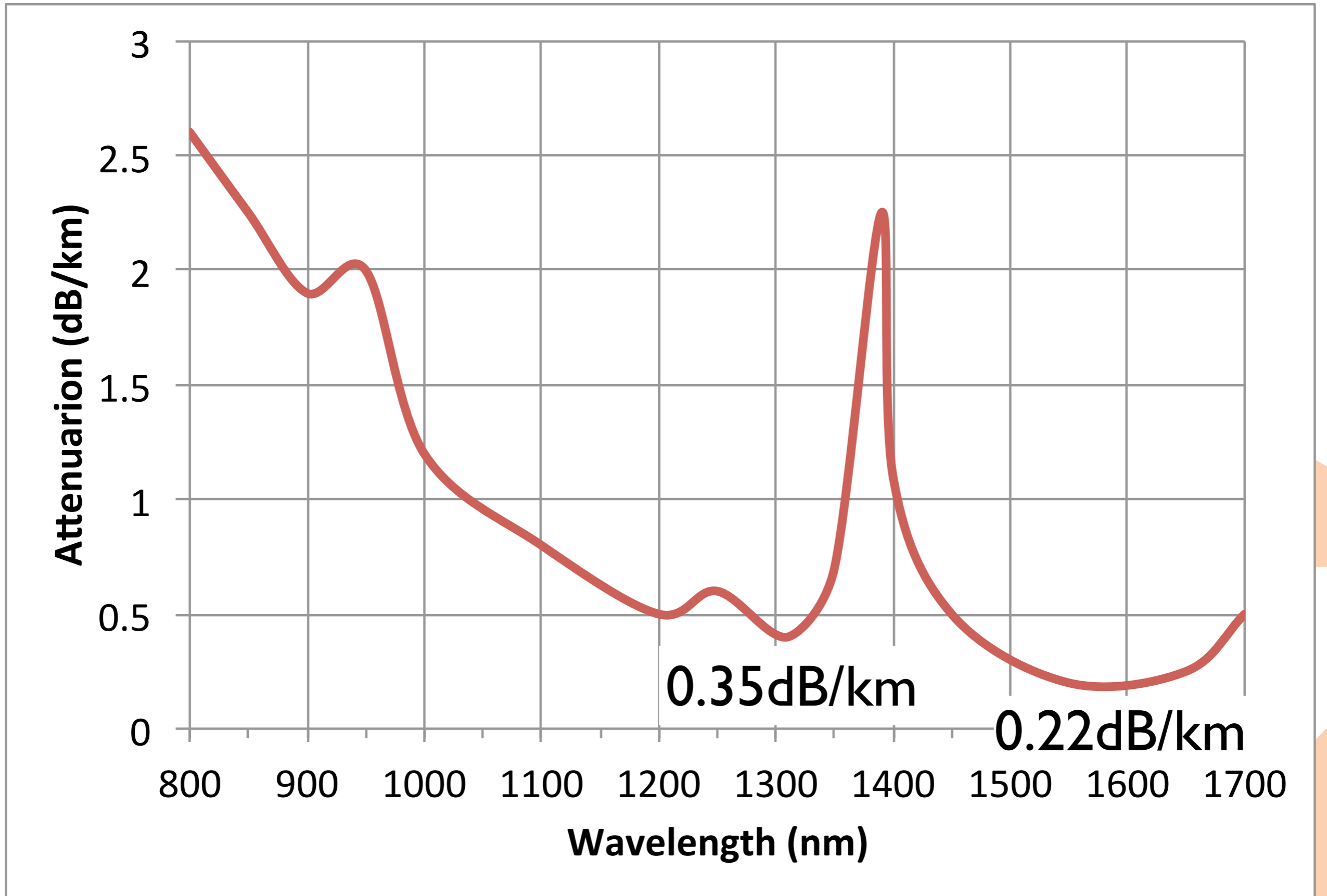
Problem Statement

- Currently available 100Gb/s CFPs:
 - 10x10 for 2km.
 - 100G-LR4 for 10km.
- Many of our links are too long for the available 100Gbit/s optics.
 - 100G-ER4 for 40km was (and is) not available to us.

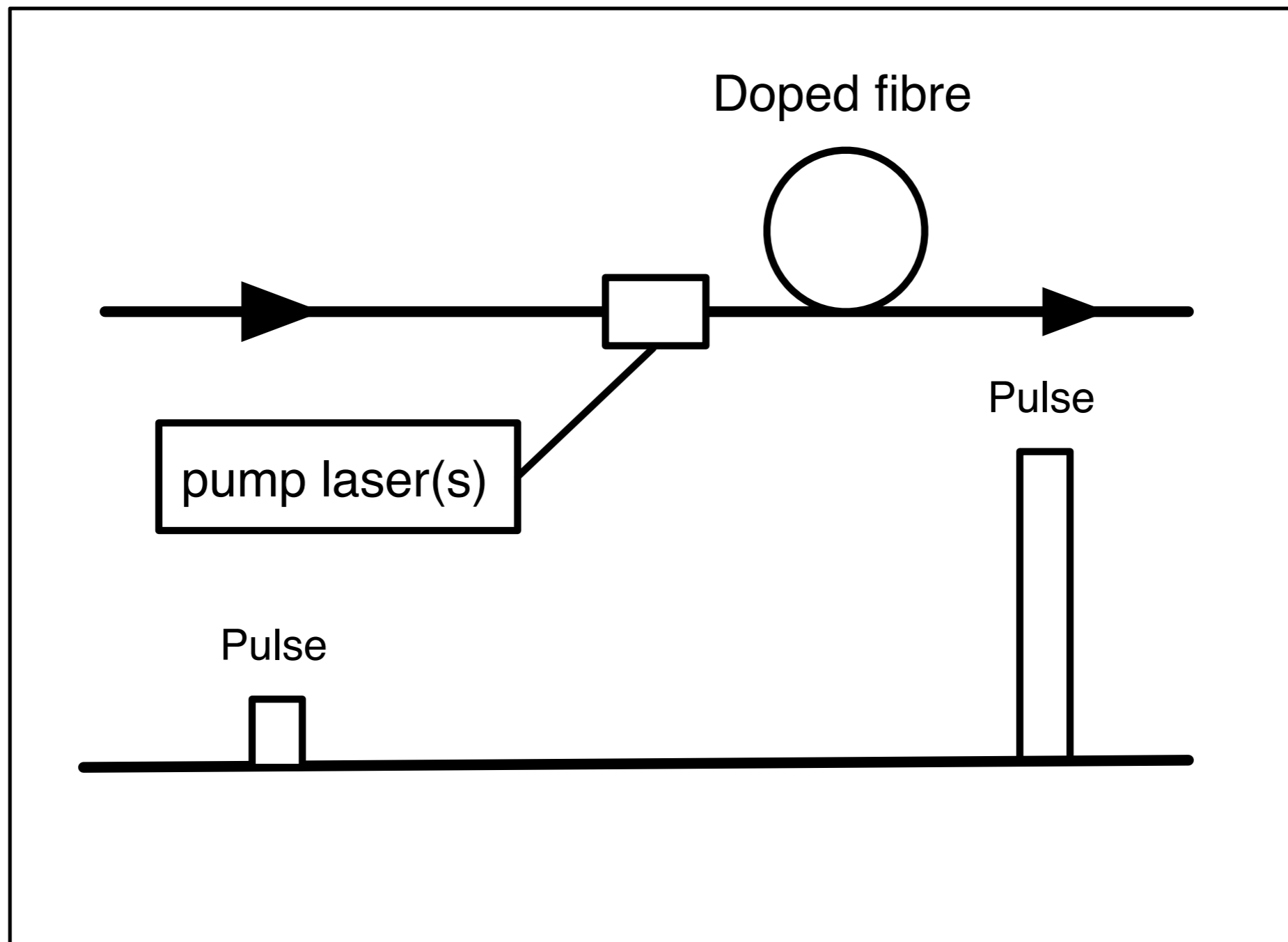
Solutions

- We need to extend the range of currently available 100Gbit/s technology up to about 32km.
- What do we have to deal with?
 - Attenuation
 - Dispersion
- What are the options?
 - Amplification
 - Transmission equipment

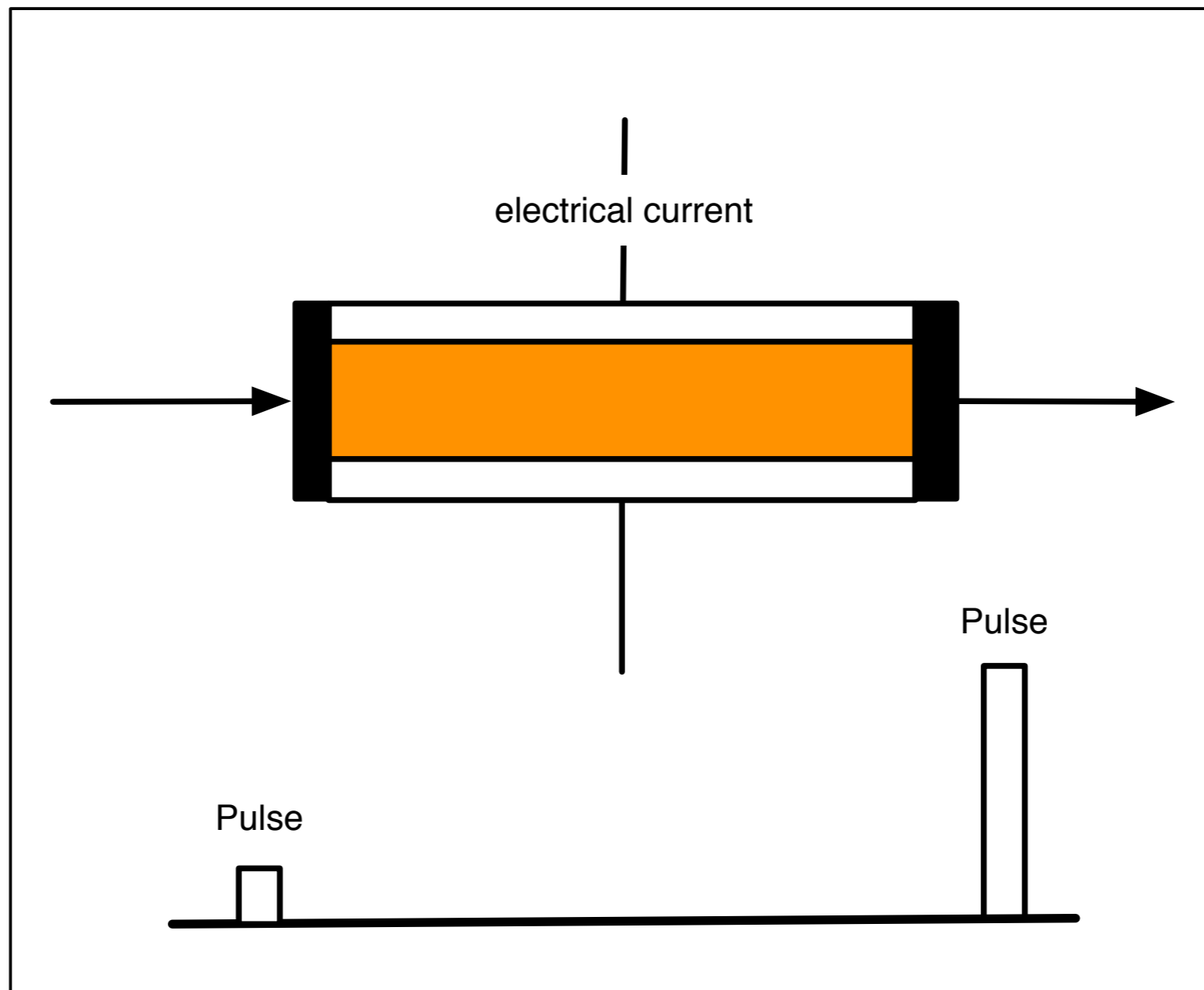




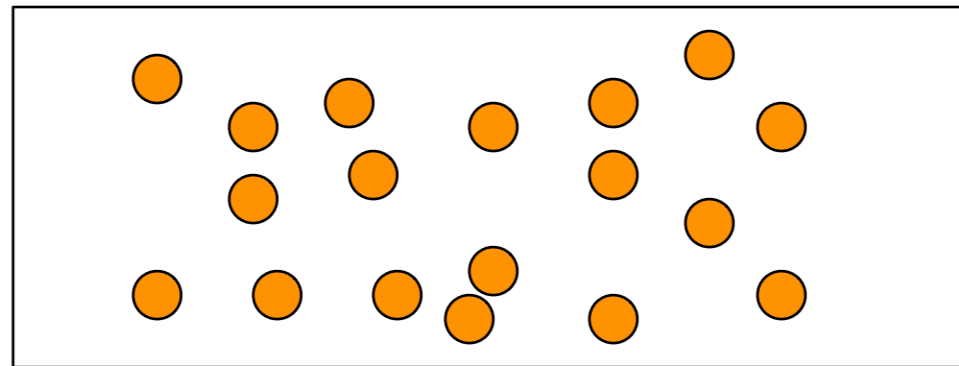
Doped Fibre Amplifier



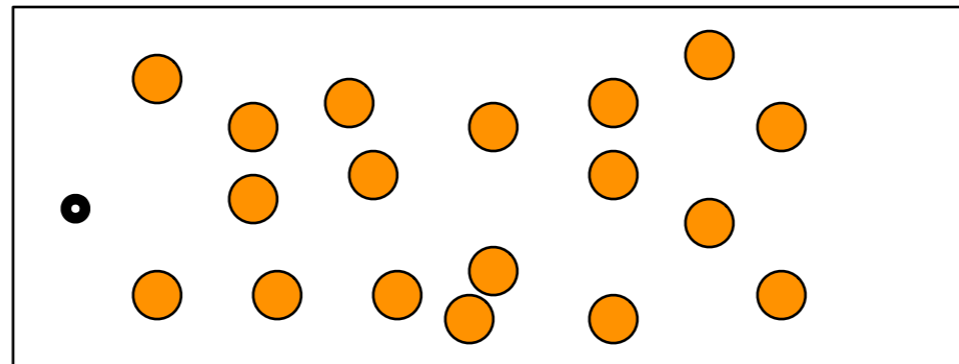
Semiconductor



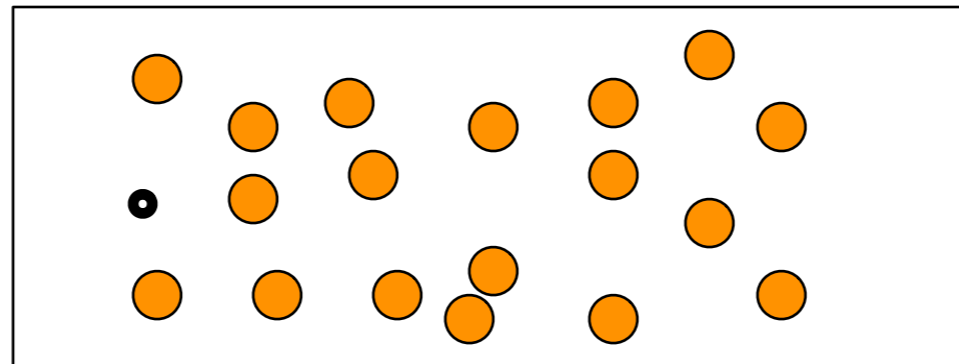
Optical Amplifier



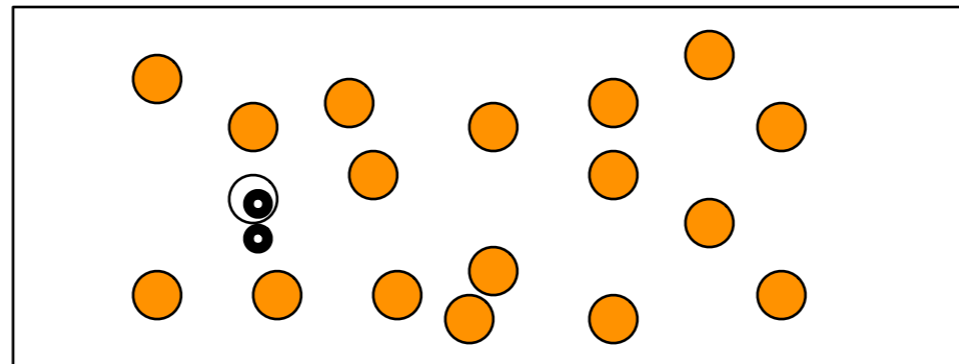
Optical Amplifier



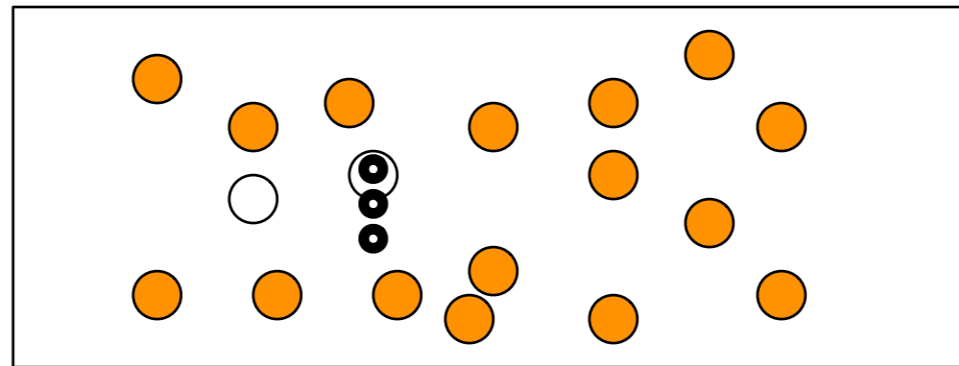
Optical Amplifier



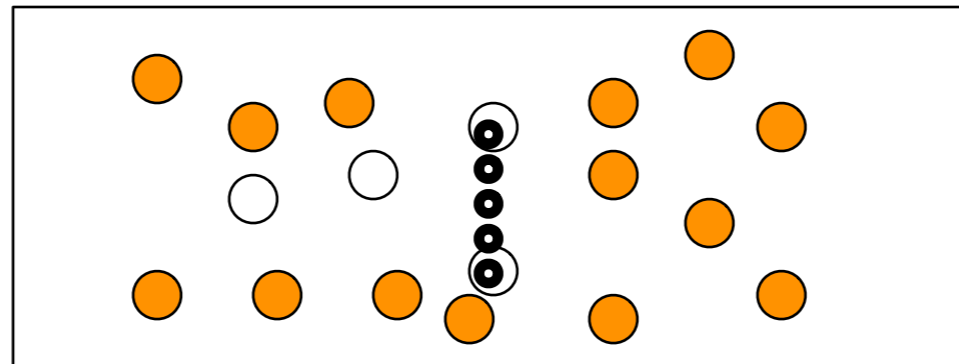
Optical Amplifier



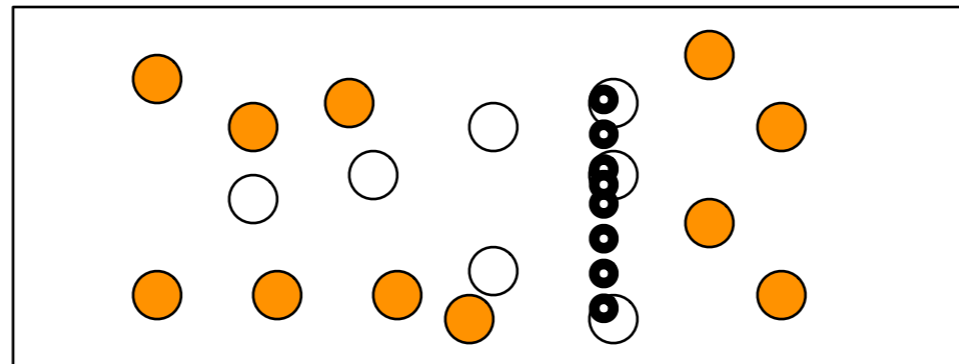
Optical Amplifier



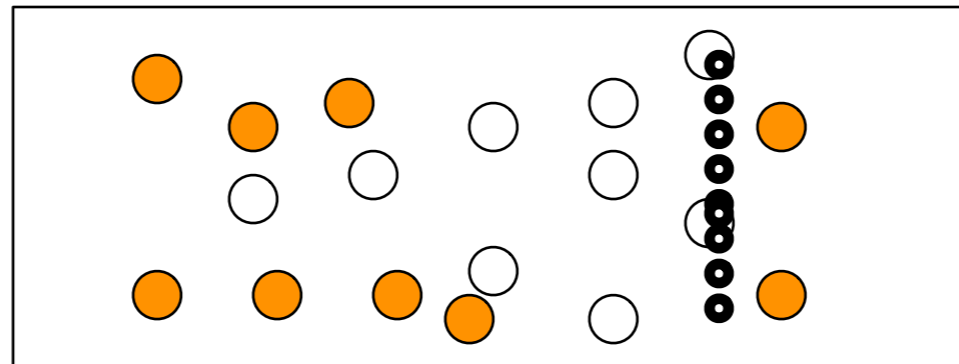
Optical Amplifier



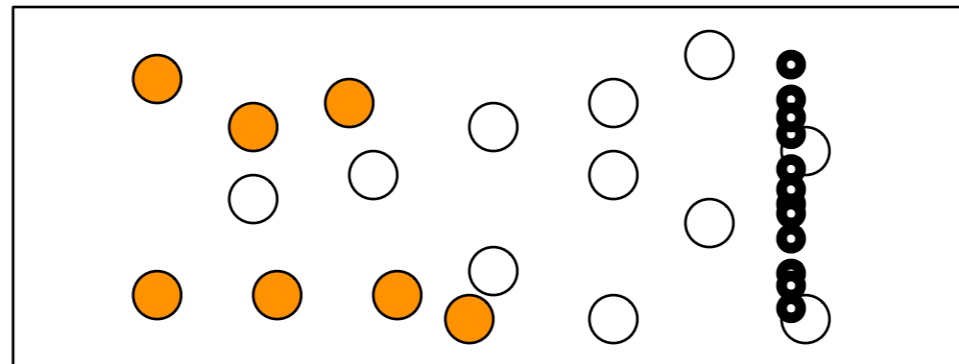
Optical Amplifier



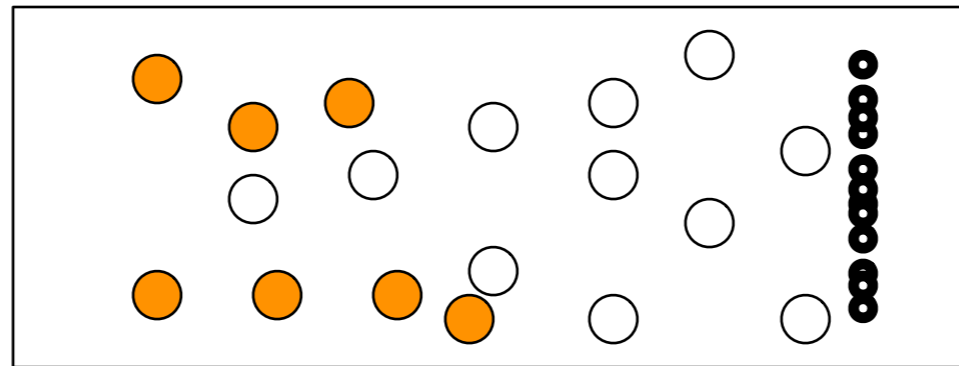
Optical Amplifier



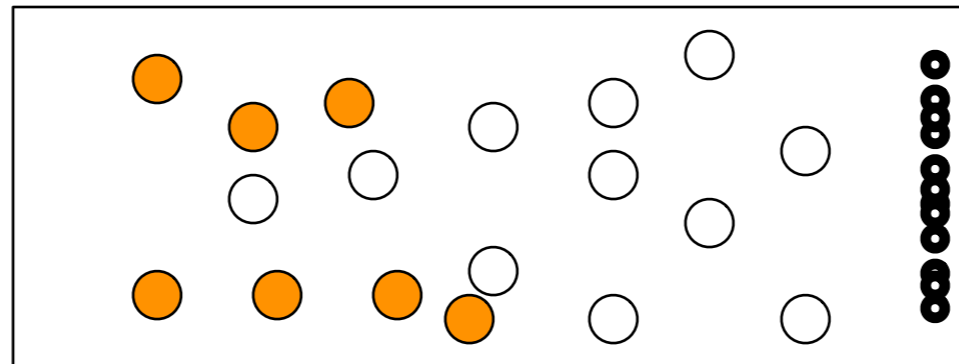
Optical Amplifier



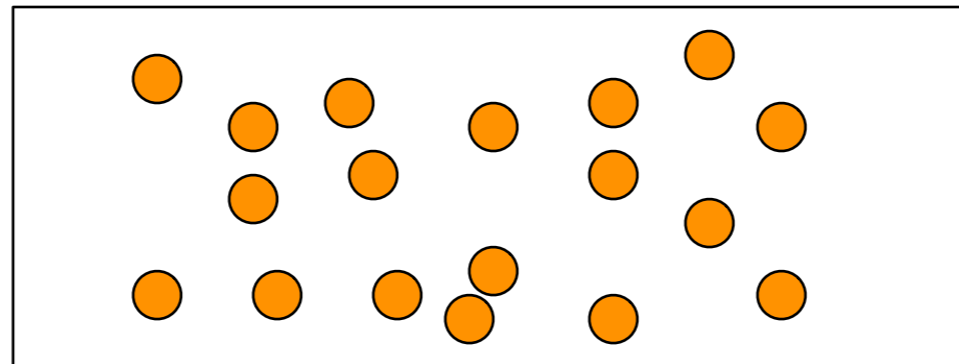
Optical Amplifier

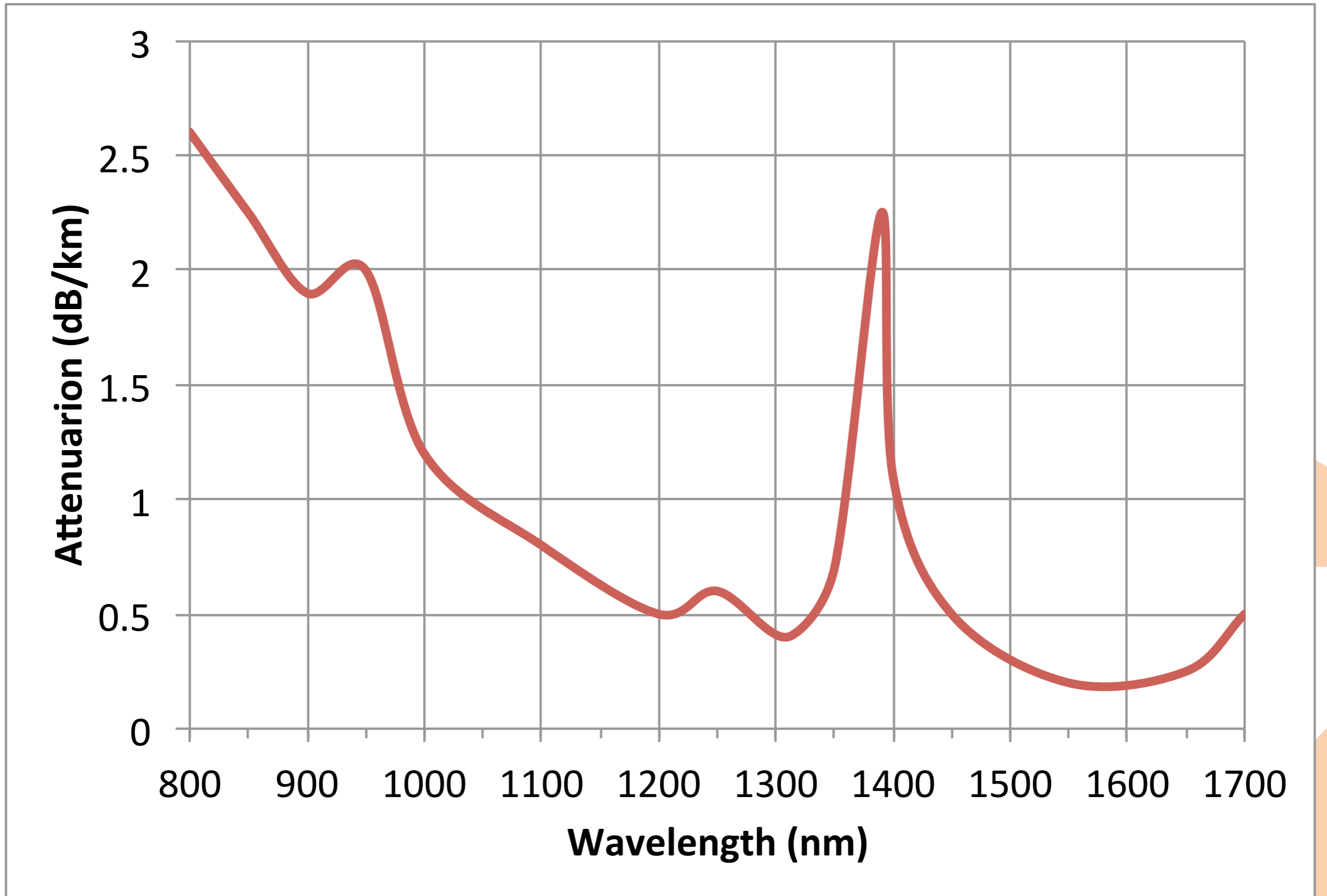


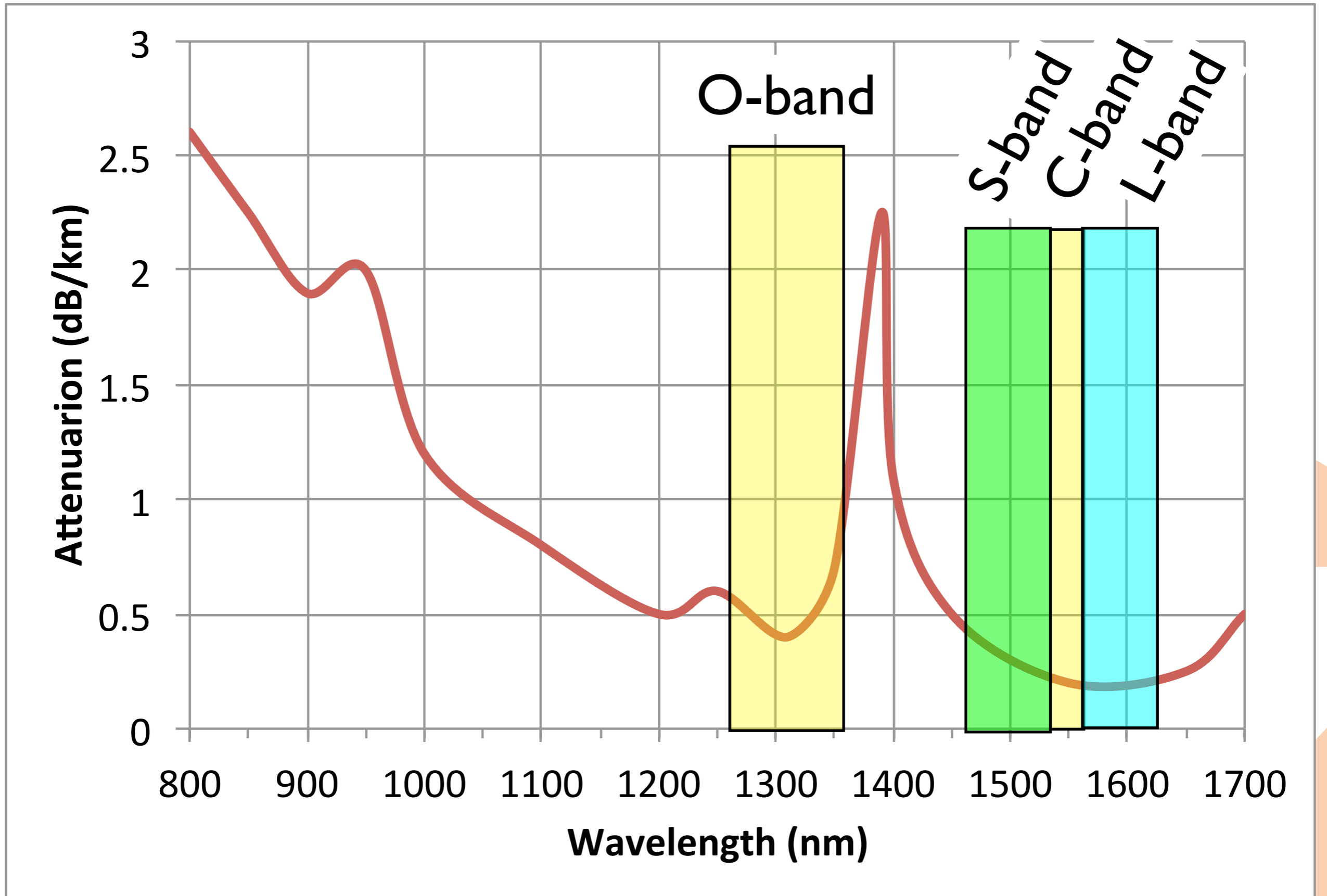
Optical Amplifier



Optical Amplifier

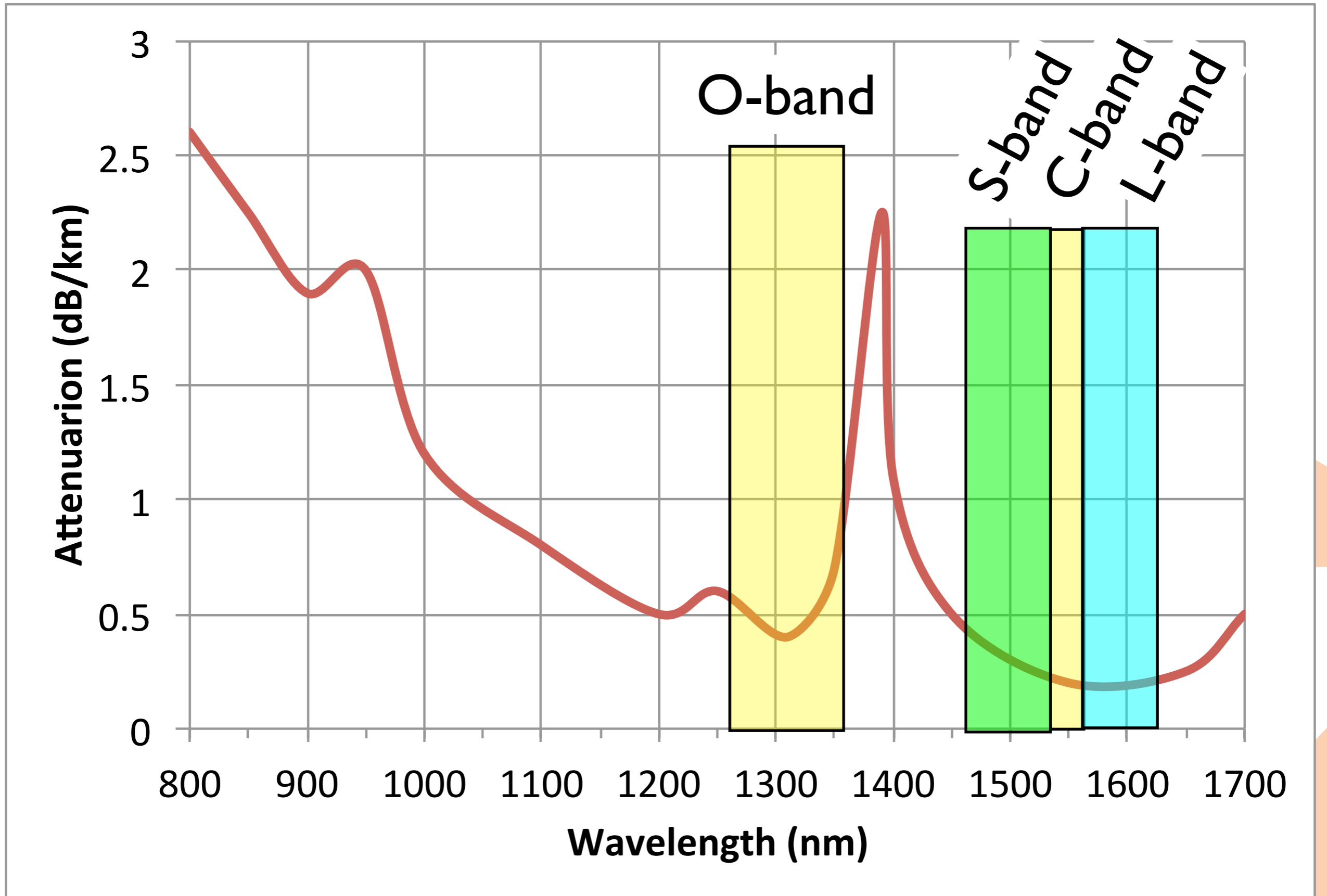


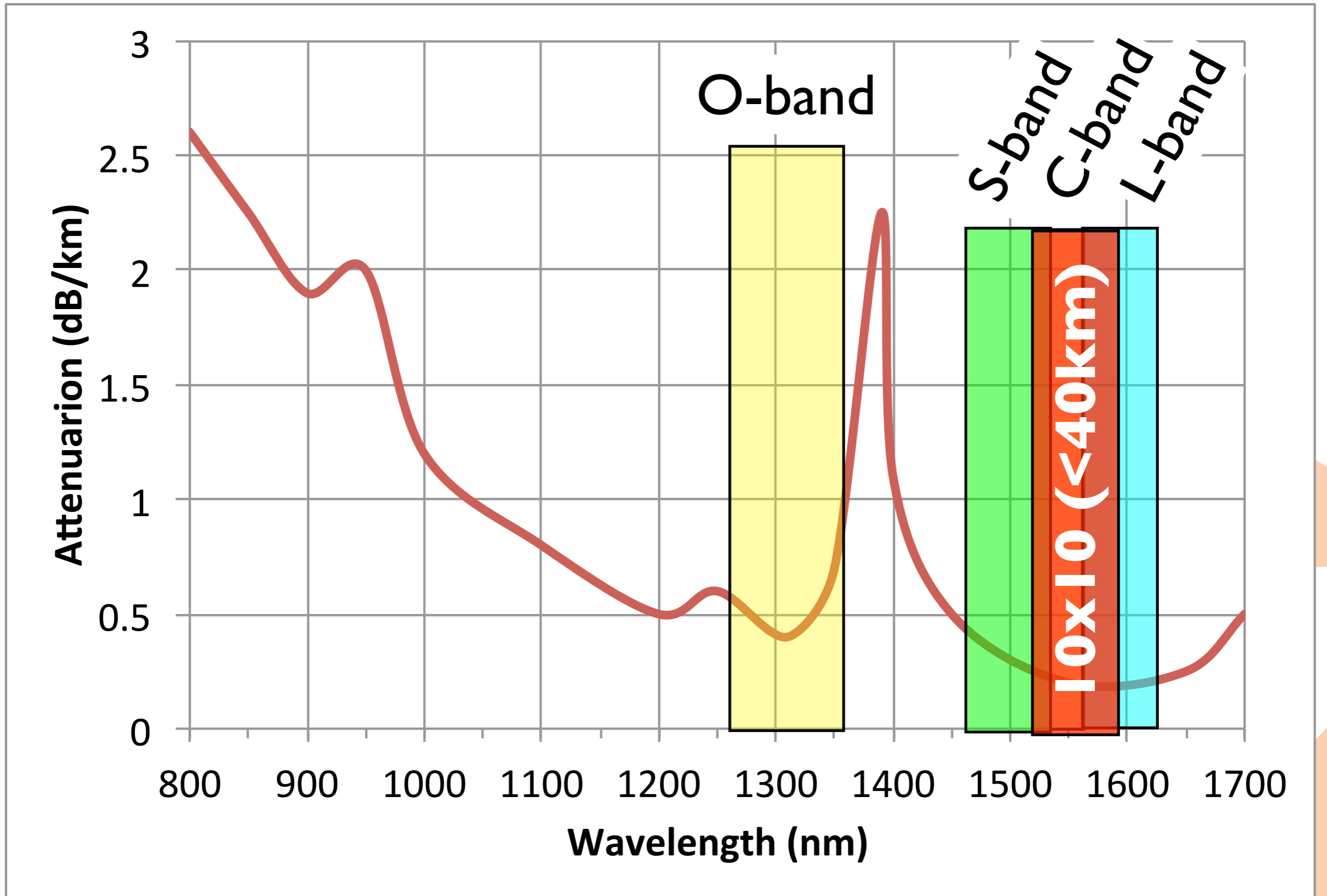




Band	Doped Fibre Amplifier
Original (O) 1260 to 1360 nm	PDFA (Praseodymium doped fibre amplifier)
Short wavelengths (S) 1460 to 1530 nm	TDFA (Thulium doped fibre amplifier)
Conventional (C) 1530 to 1565 nm	EDFA (C-band) (Erbium doped fibre amplifier)
Long wavelengths (L) 1565 to 1625 nm	EDFA (L-band) (Erbium doped fibre amplifier)

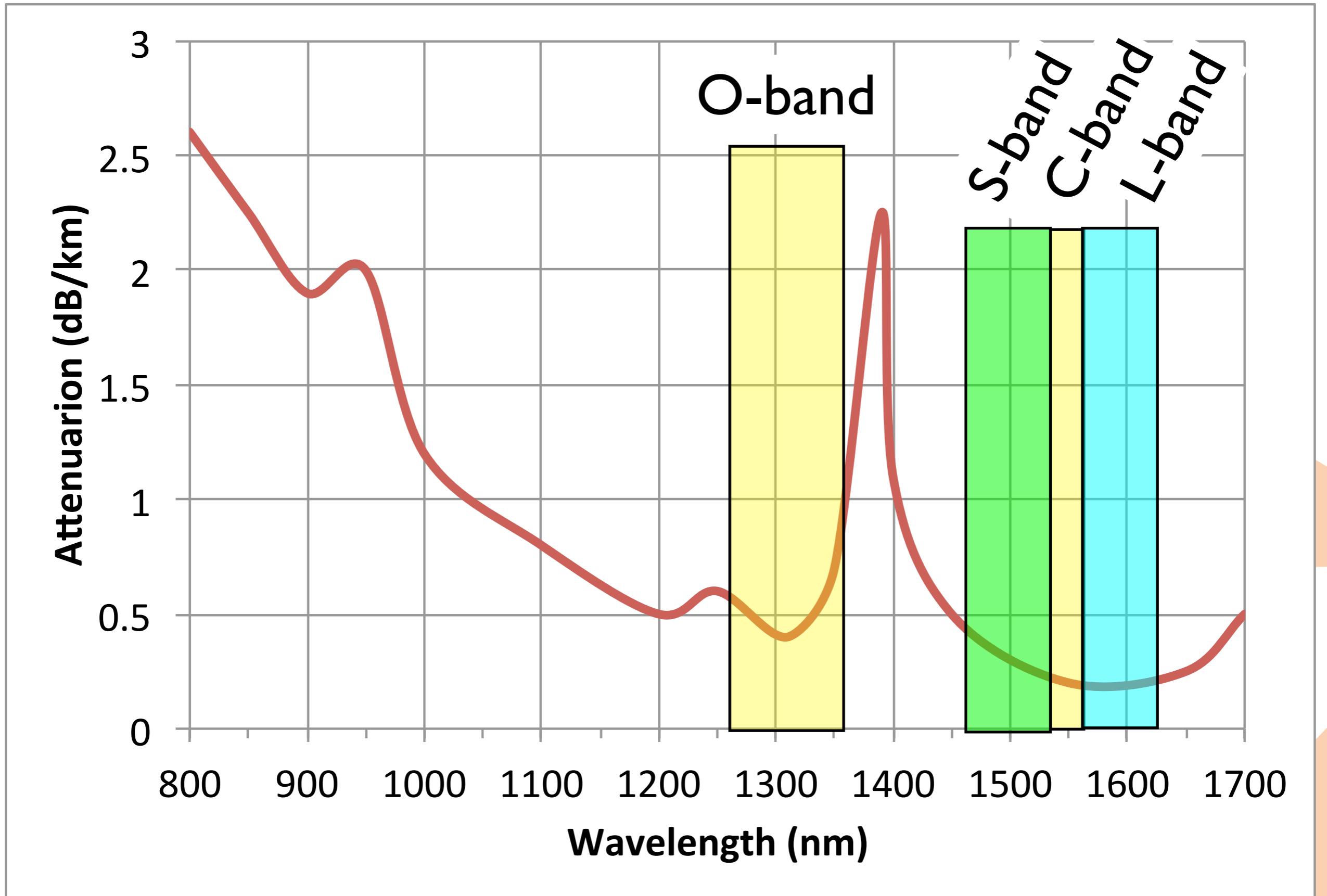
Lane	Center λ (nm)	λ Range (nm)
L ₀	1523	1521 to 1525
L ₁	1531	1529 to 1533
L ₂	1539	1537 to 1541
L ₃	1547	1545 to 1549
L ₄	1555	1553 to 1557
L ₅	1563	1561 to 1565
L ₆	1571	1569 to 1573
L ₇	1579	1577 to 1581
L ₈	1587	1585 to 1589
L ₉	1595	1593 to 1597

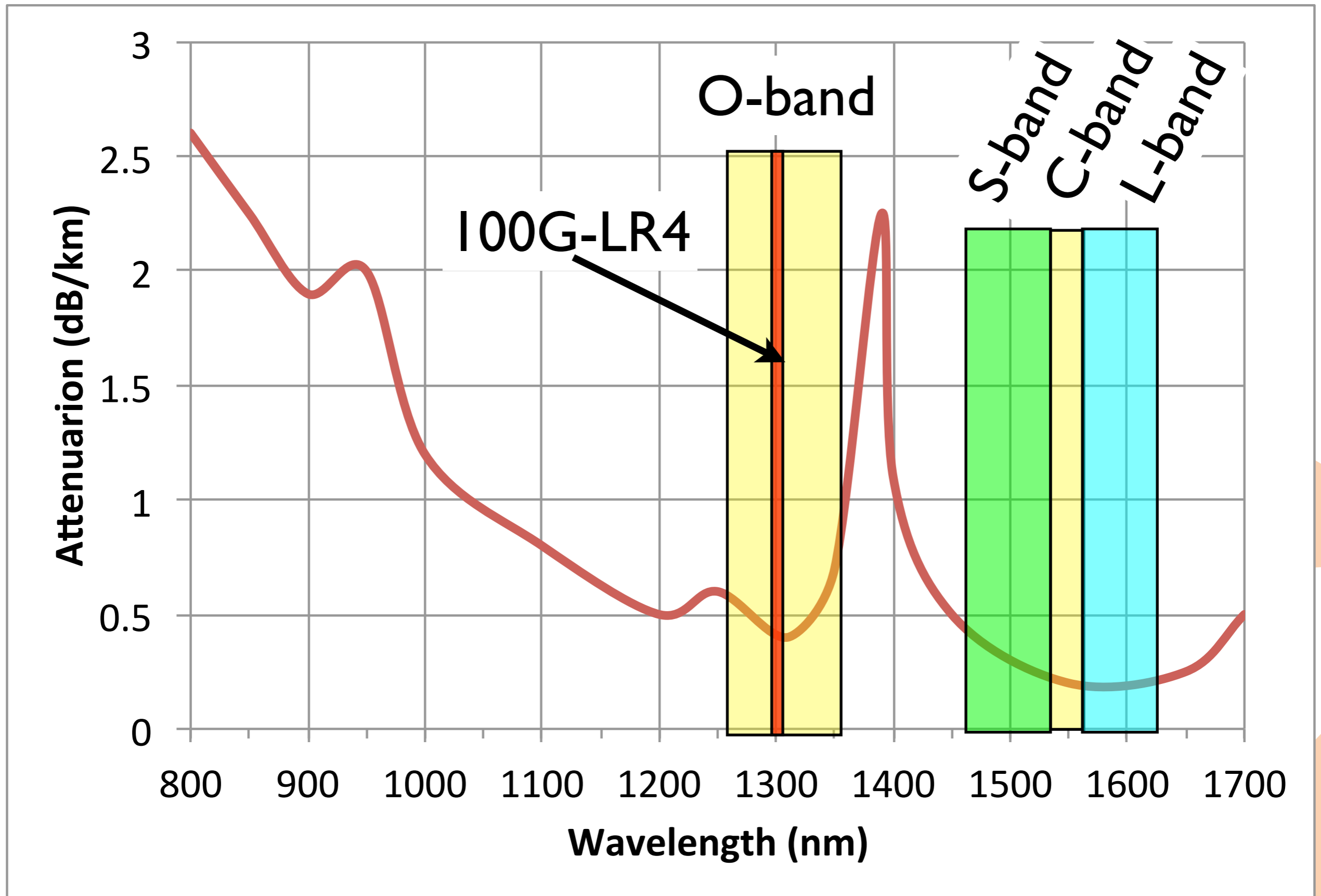




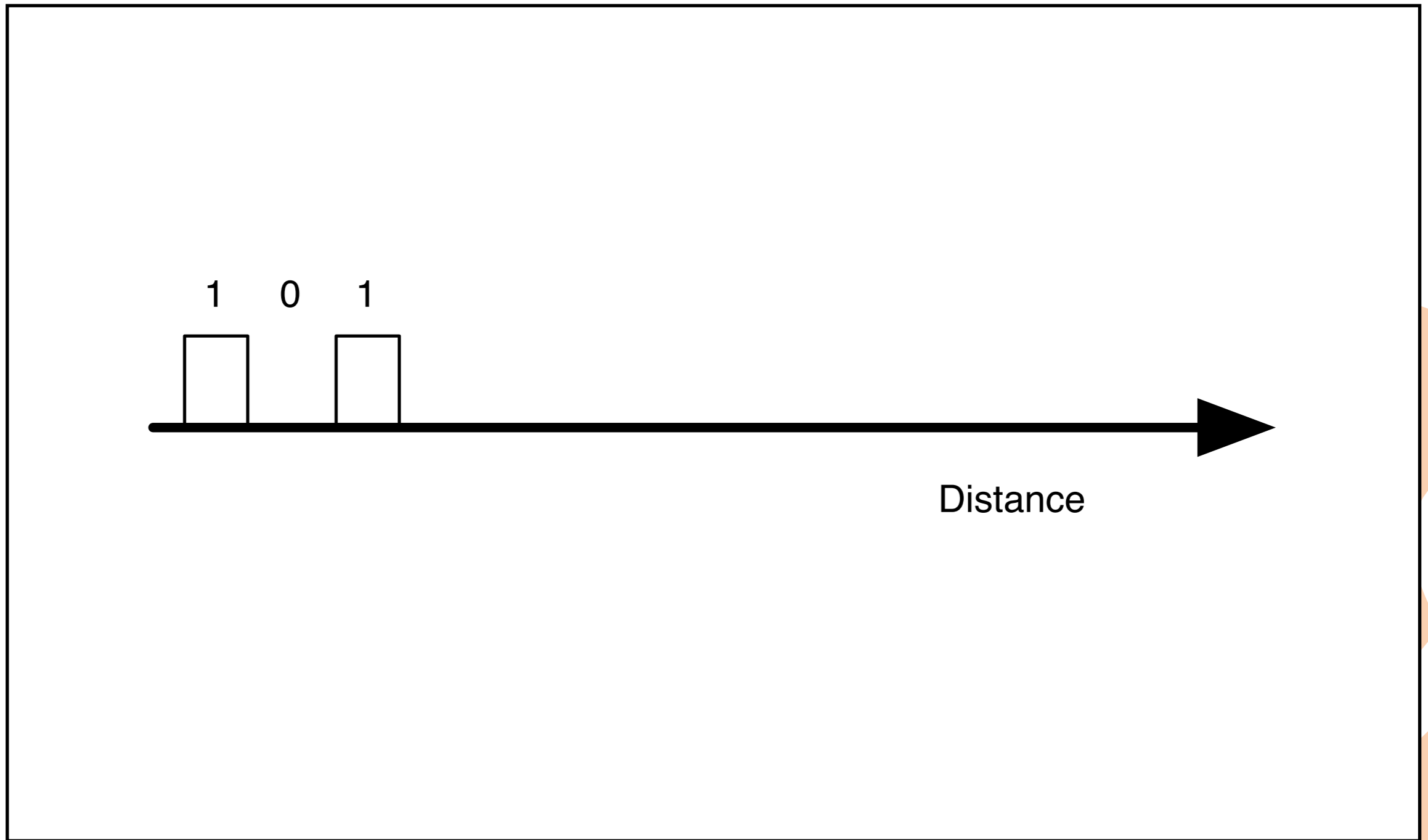
100G-LR4

Lane	Center λ (nm)	λ Range (nm)
L ₀	1295.56	1294.53 to 1296.59
L ₁	1300.055	1299.02 to 1301.09
L ₂	1304.585	1303.54 to 1305.63
L ₃	1309.14	1308.09 to 1310.19

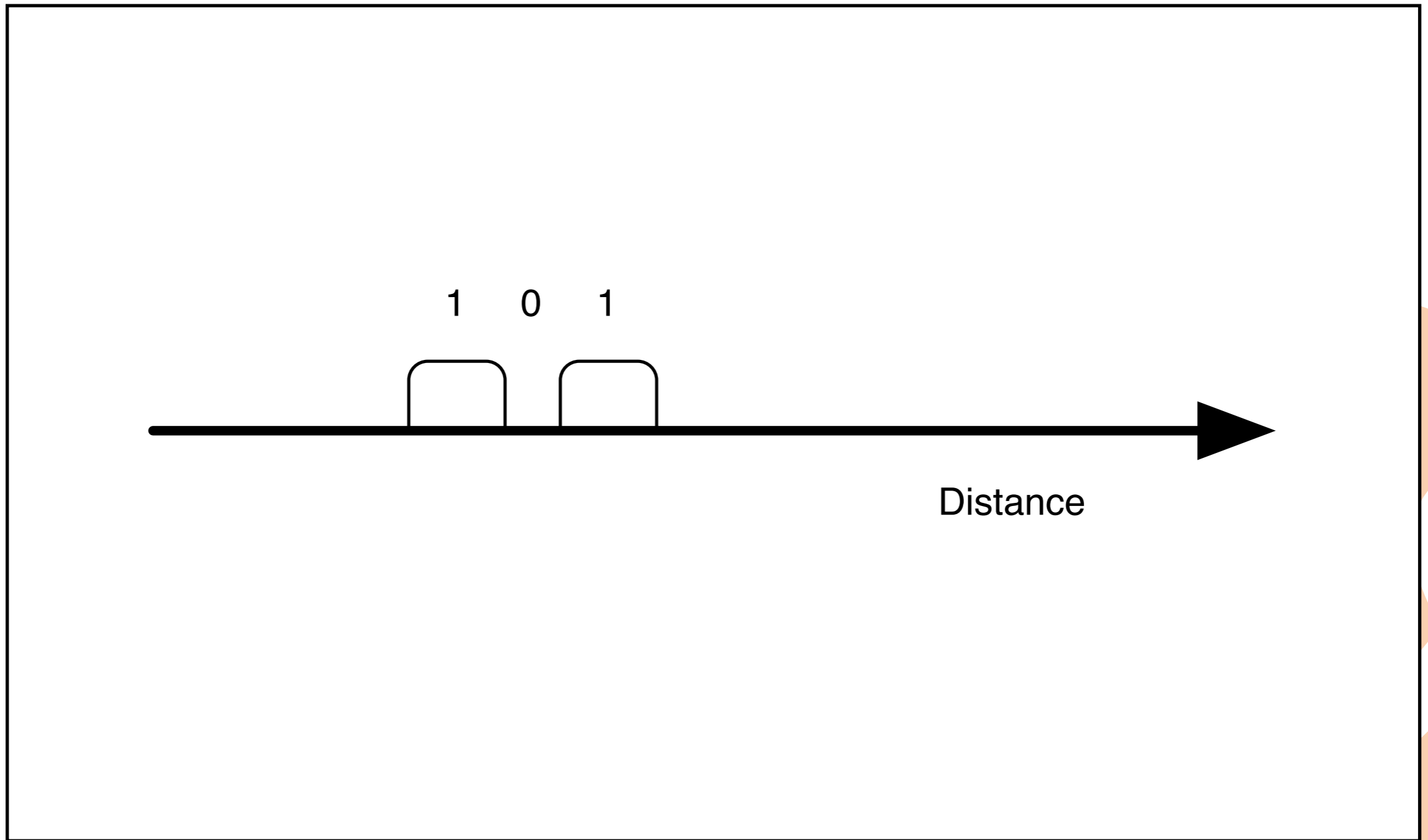




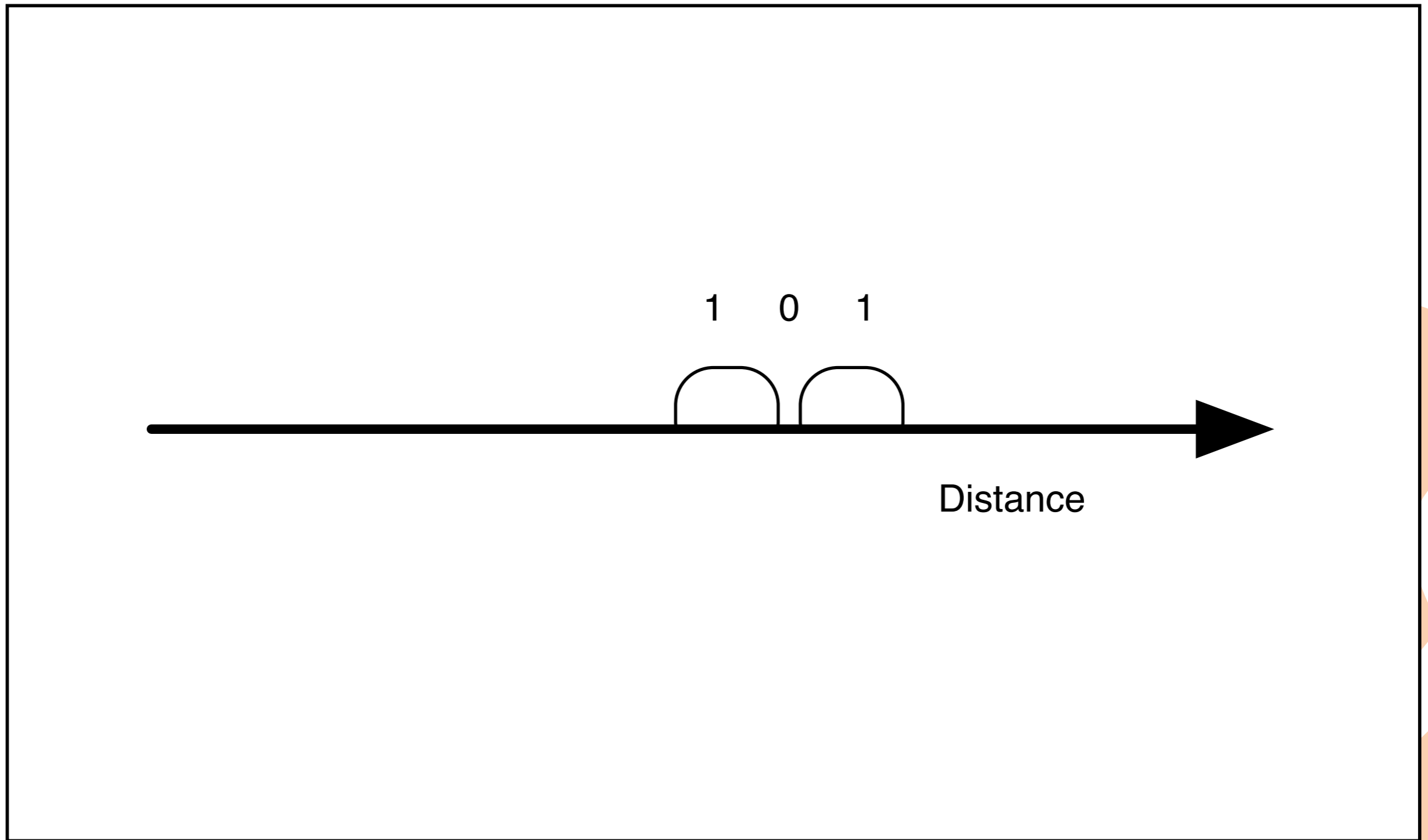
Dispersion



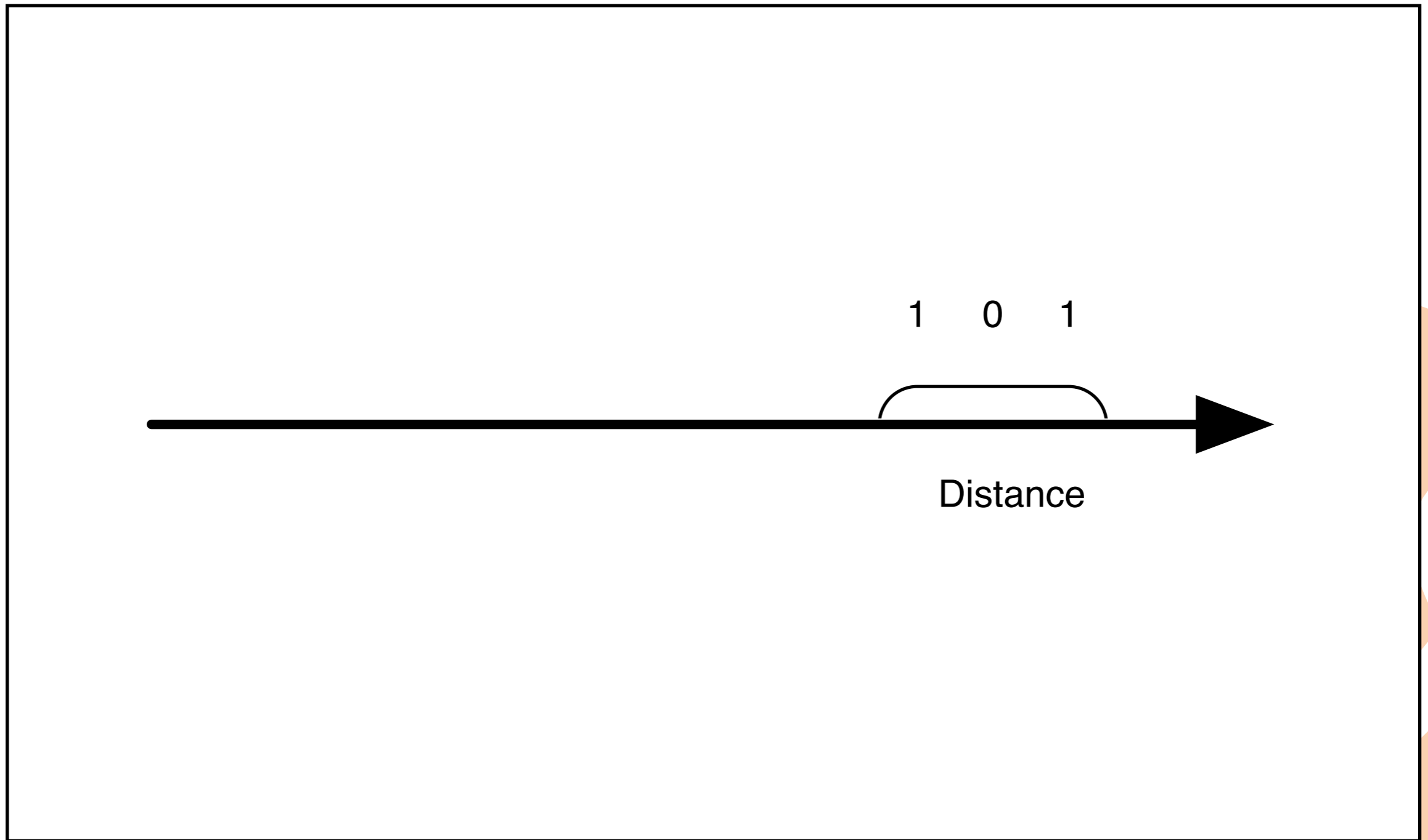
Dispersion



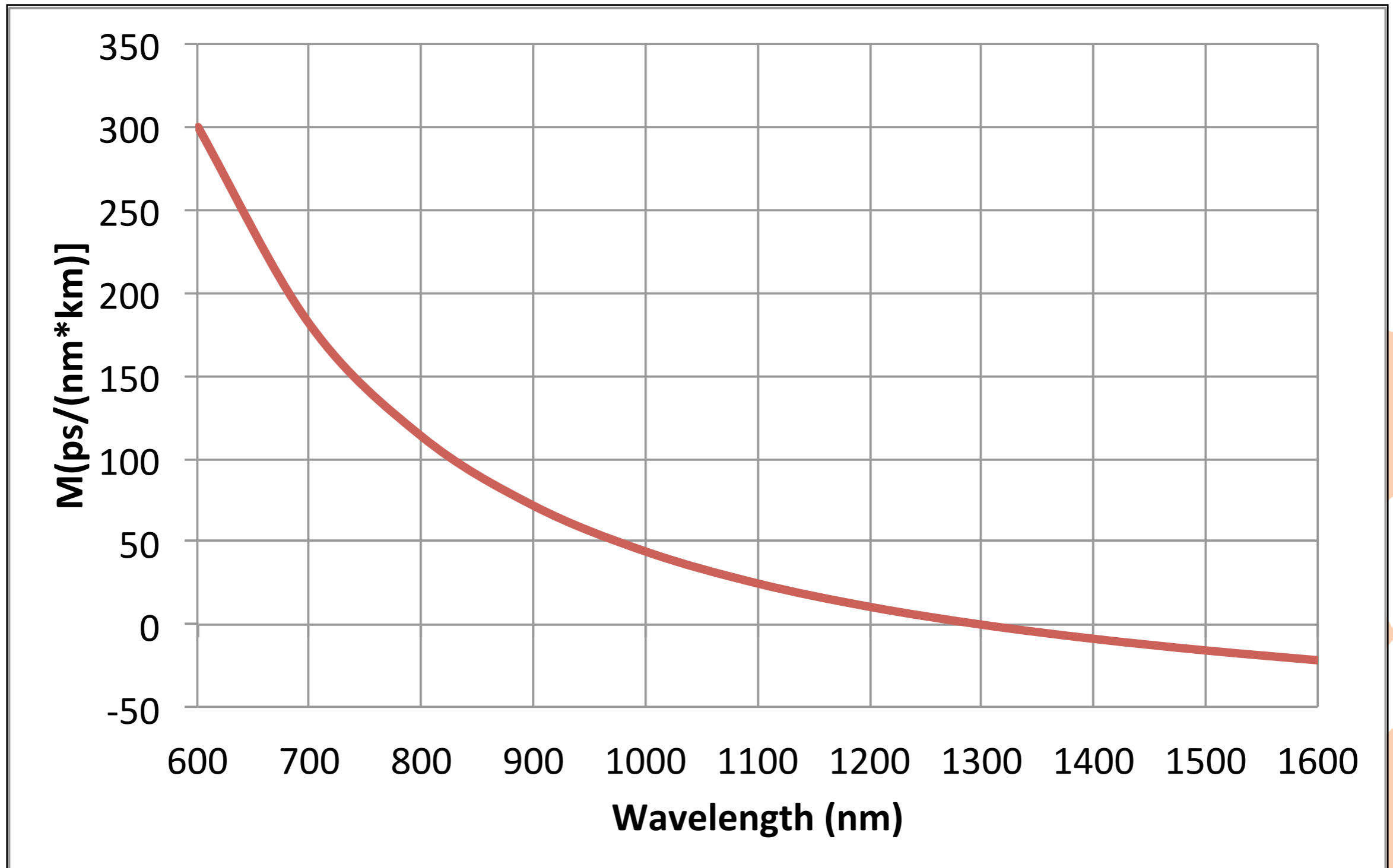
Dispersion



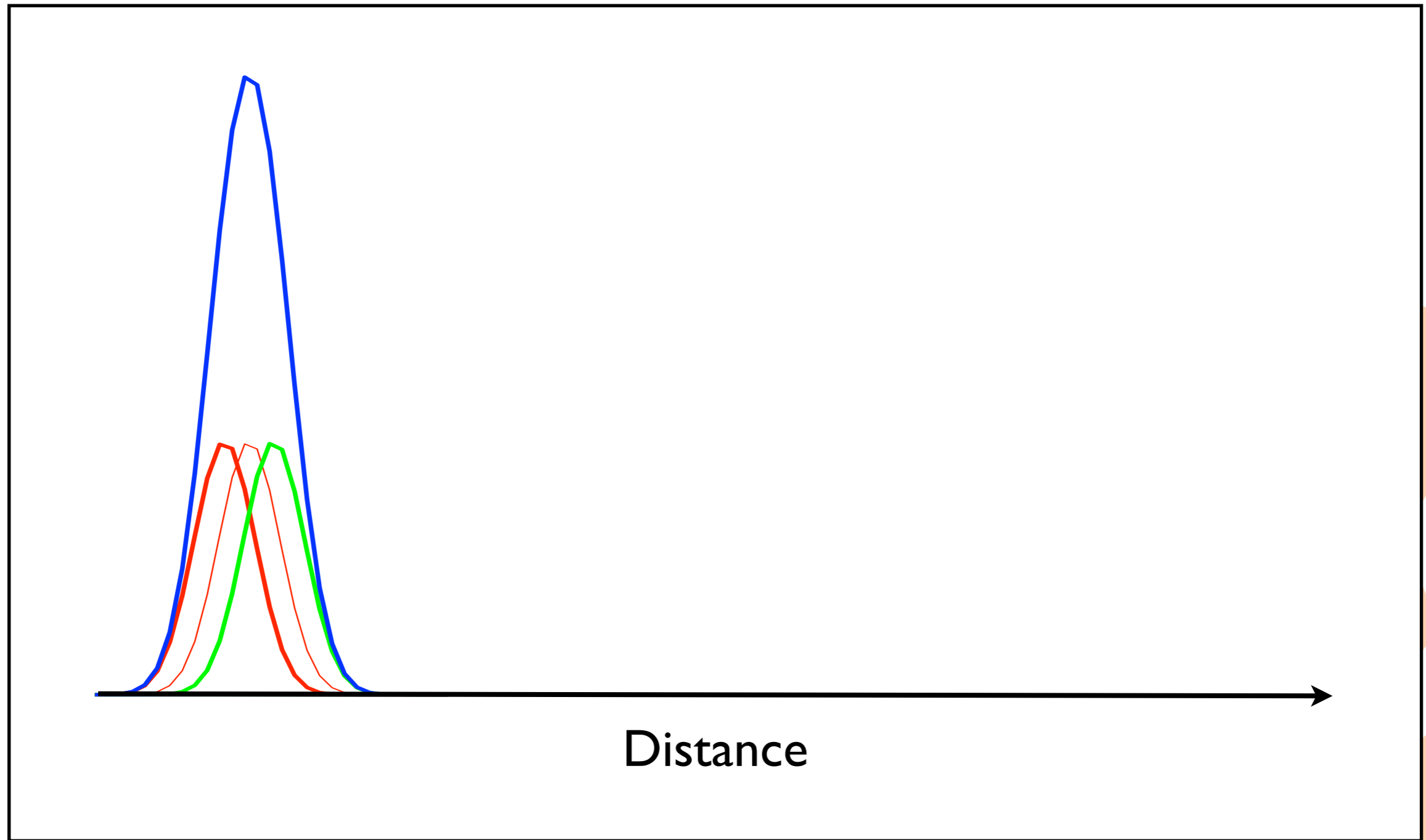
Dispersion



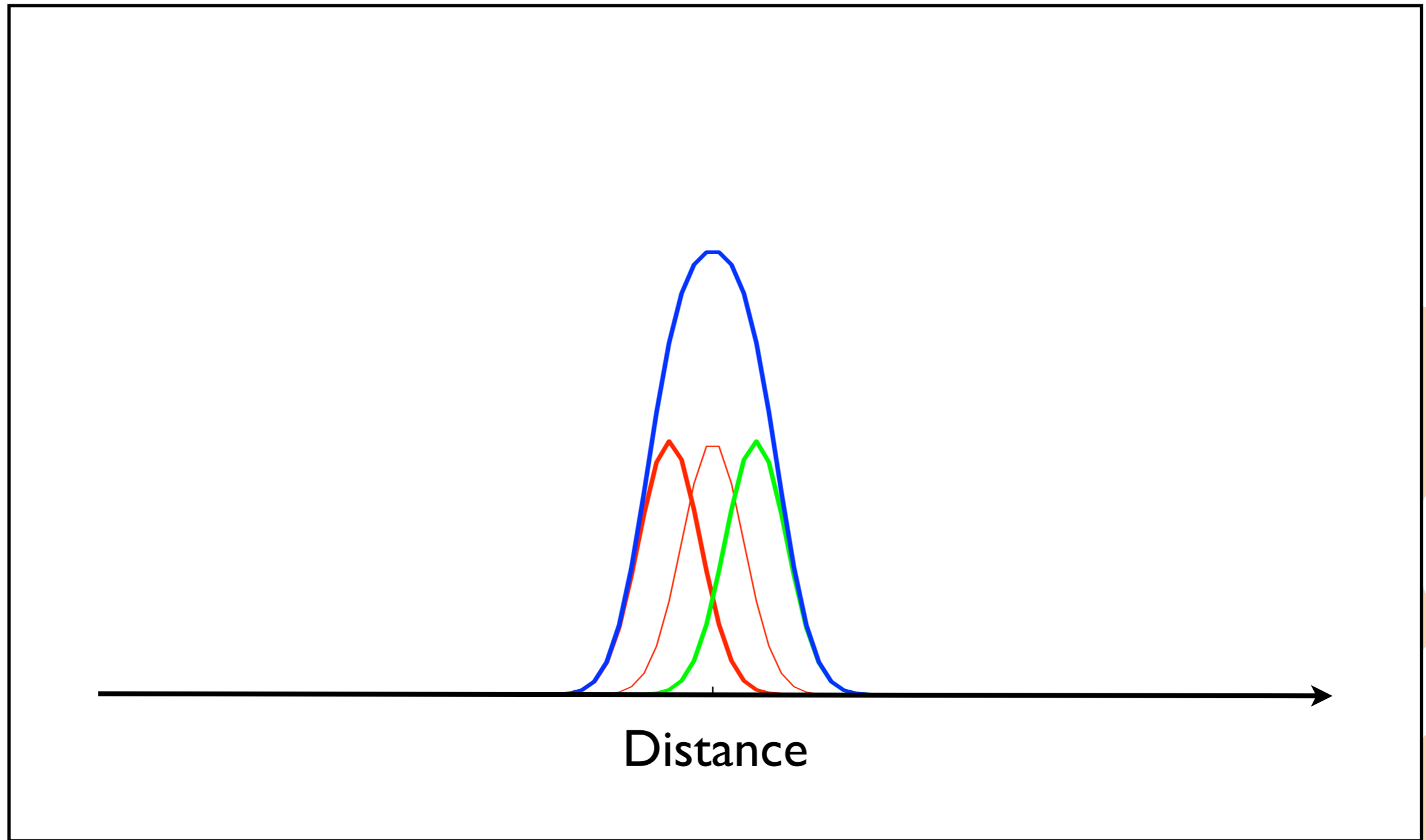
Material Dispersion



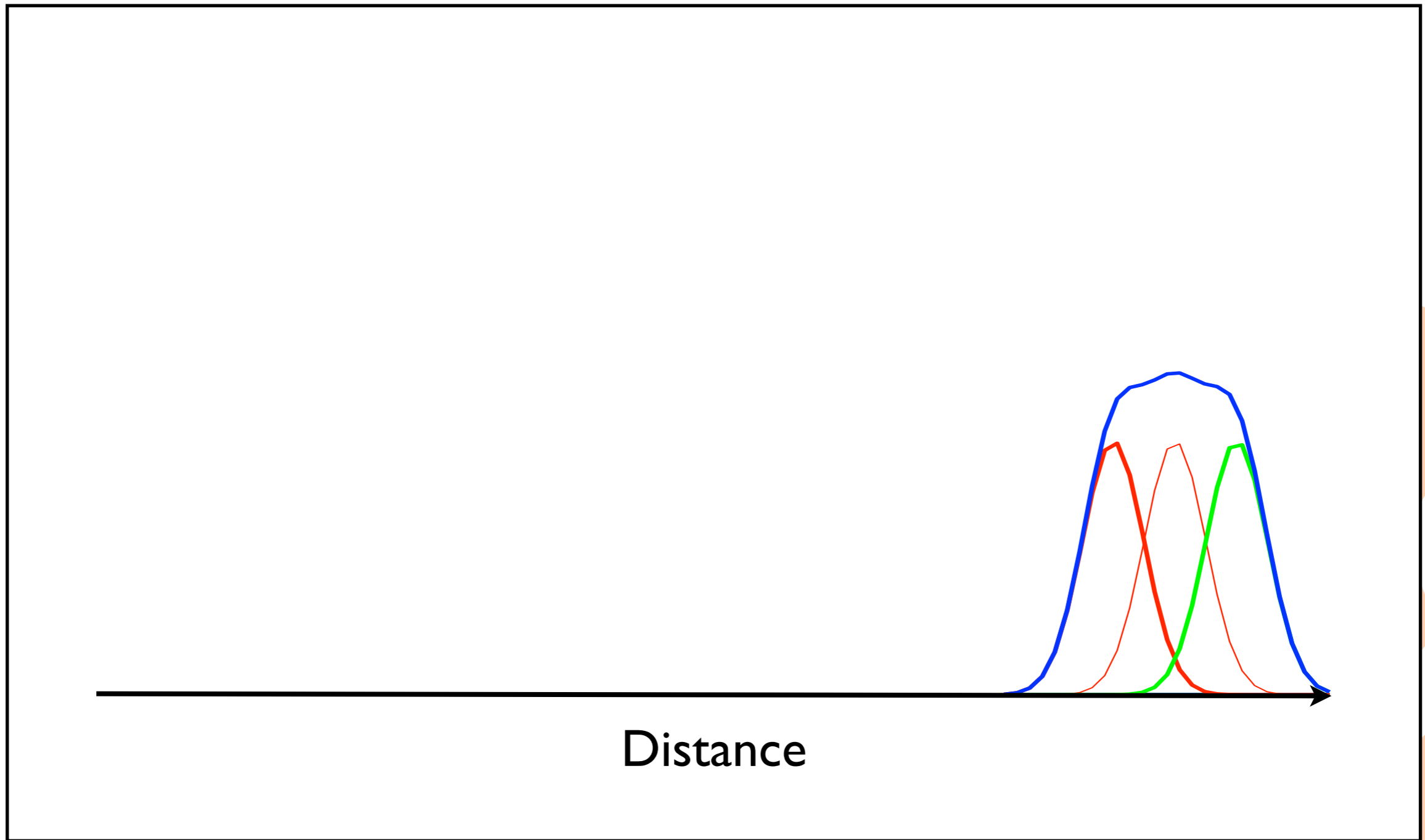
Material Dispersion



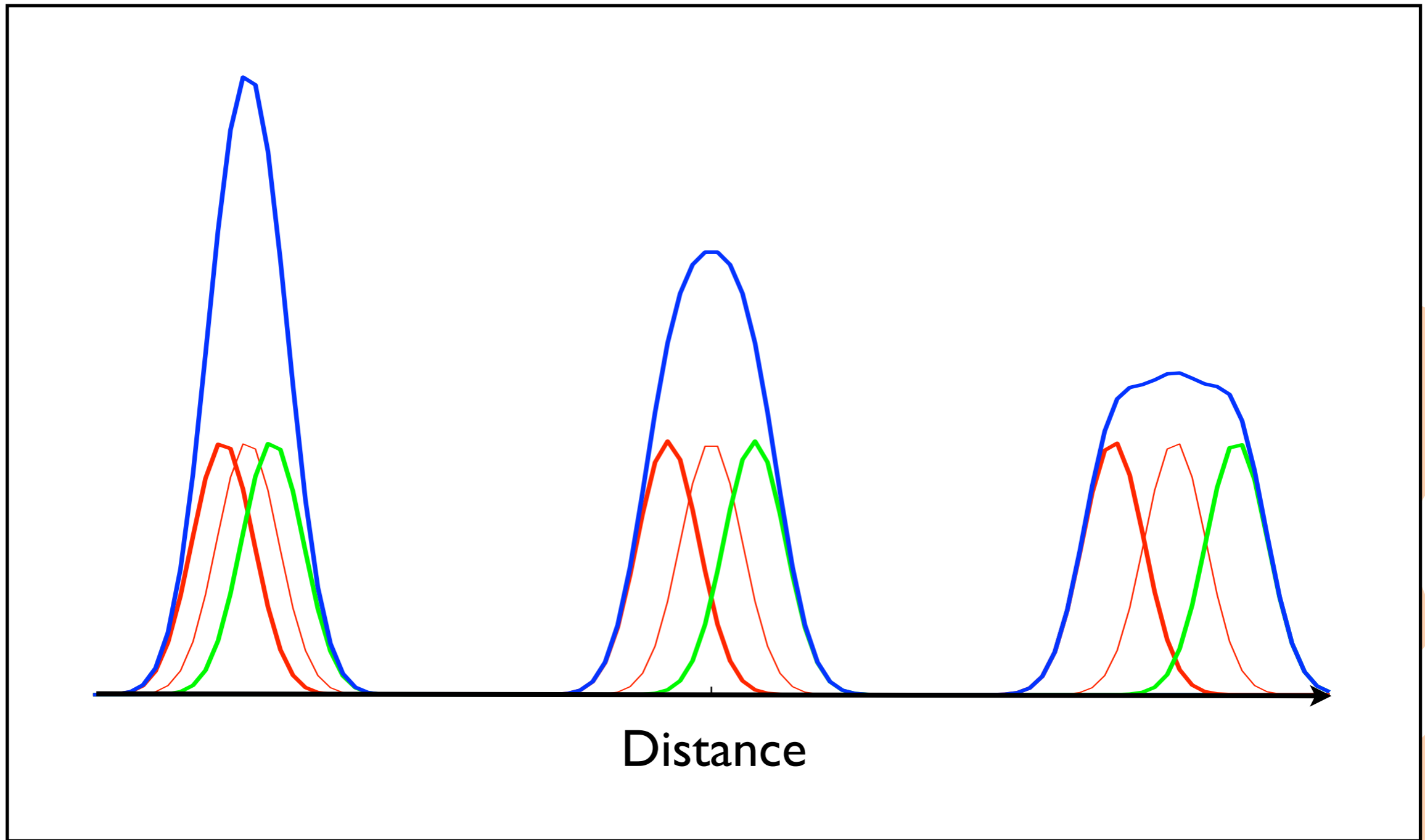
Material Dispersion



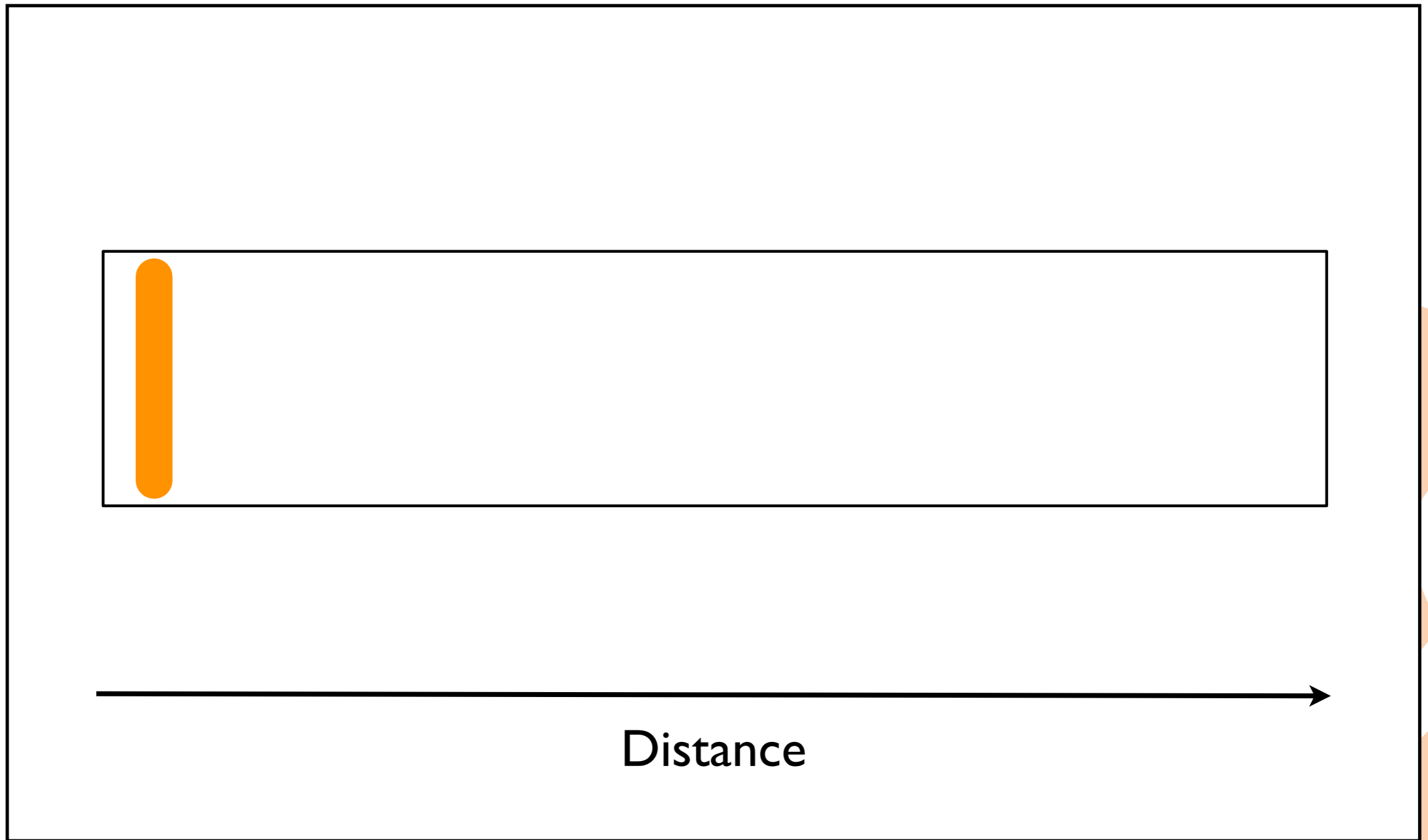
Material Dispersion



Material Dispersion



Waveguide Dispersion

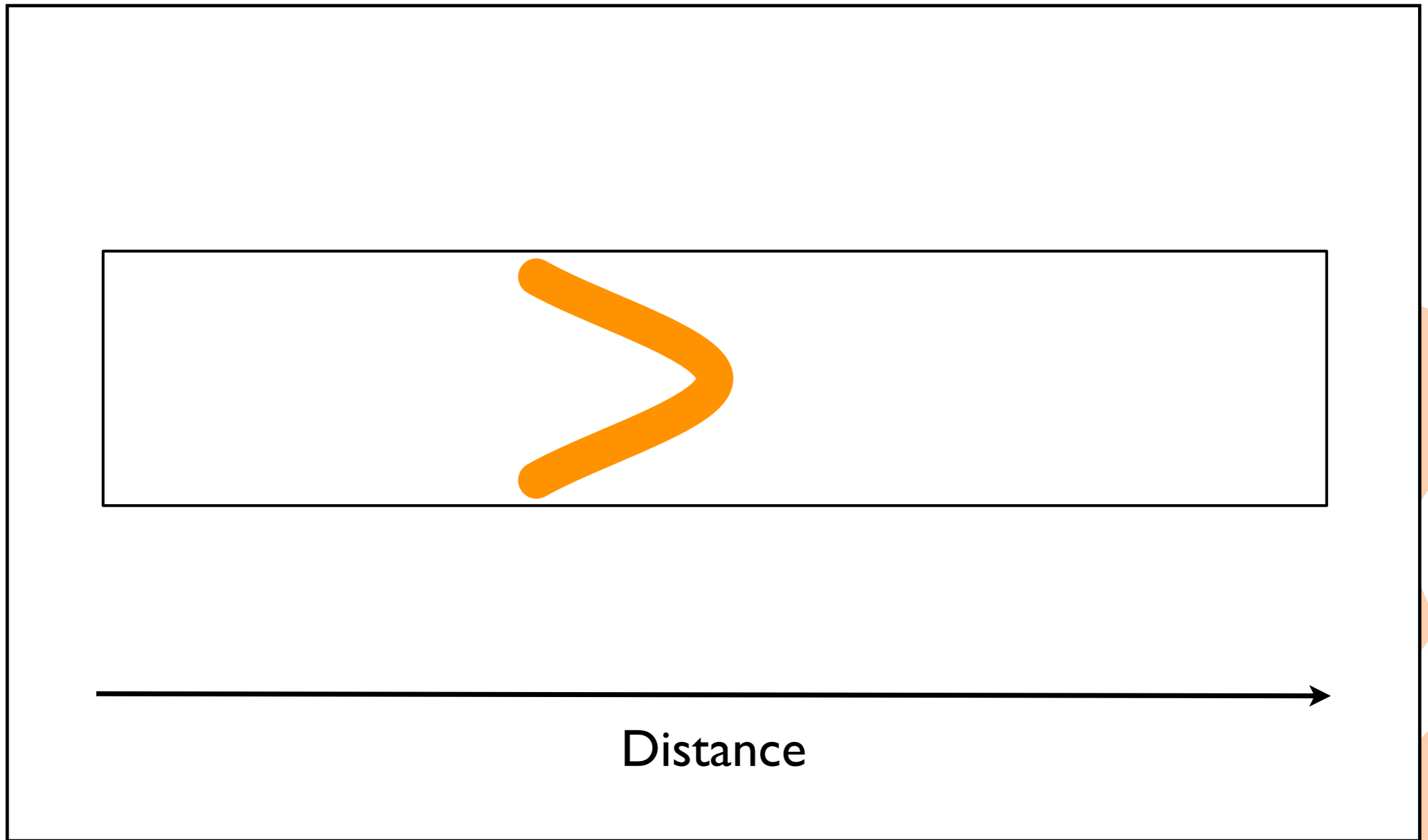


Waveguide Dispersion

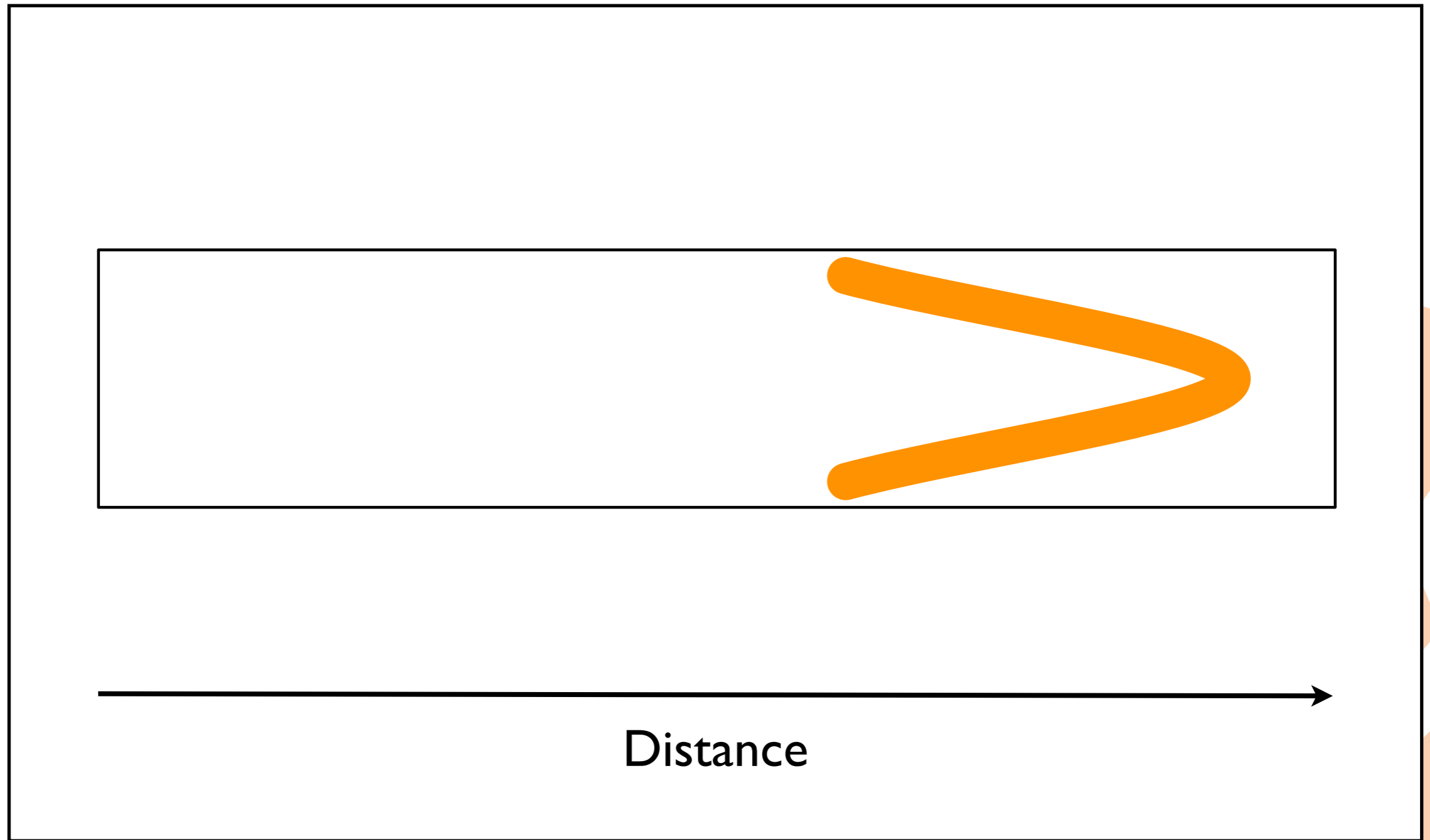


Distance

Waveguide Dispersion



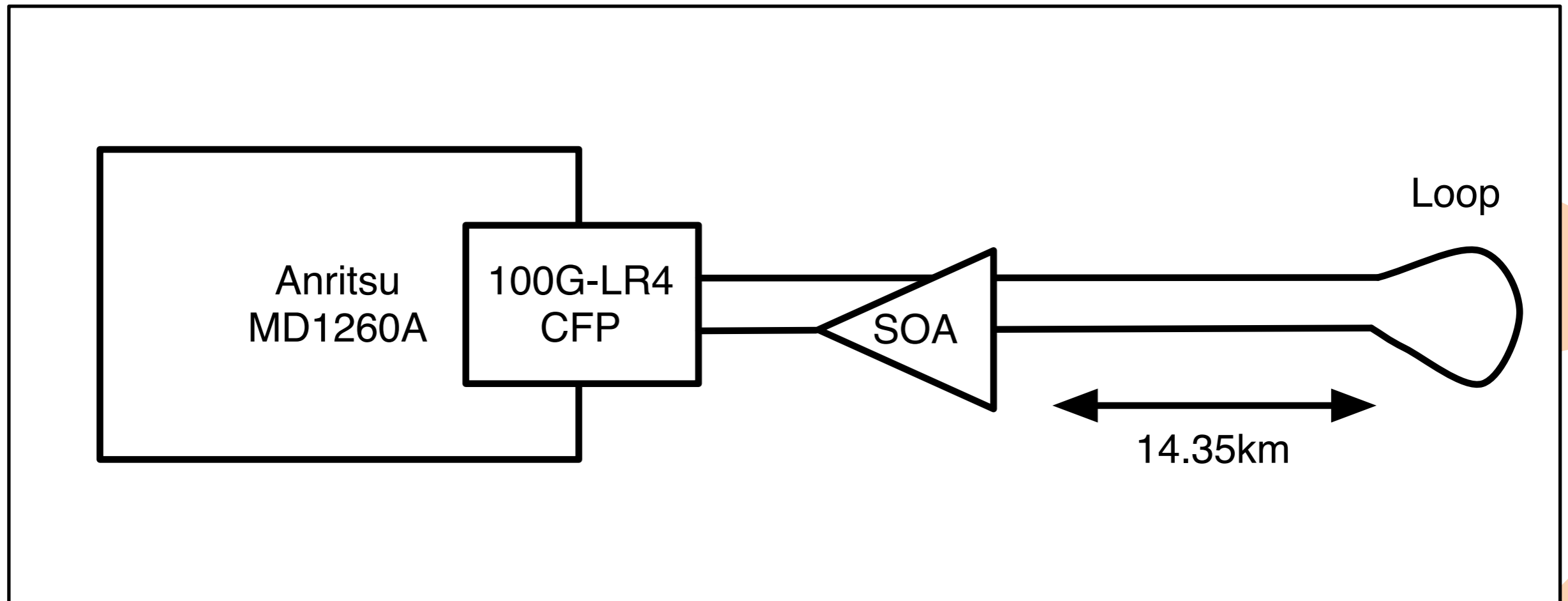
Waveguide Dispersion

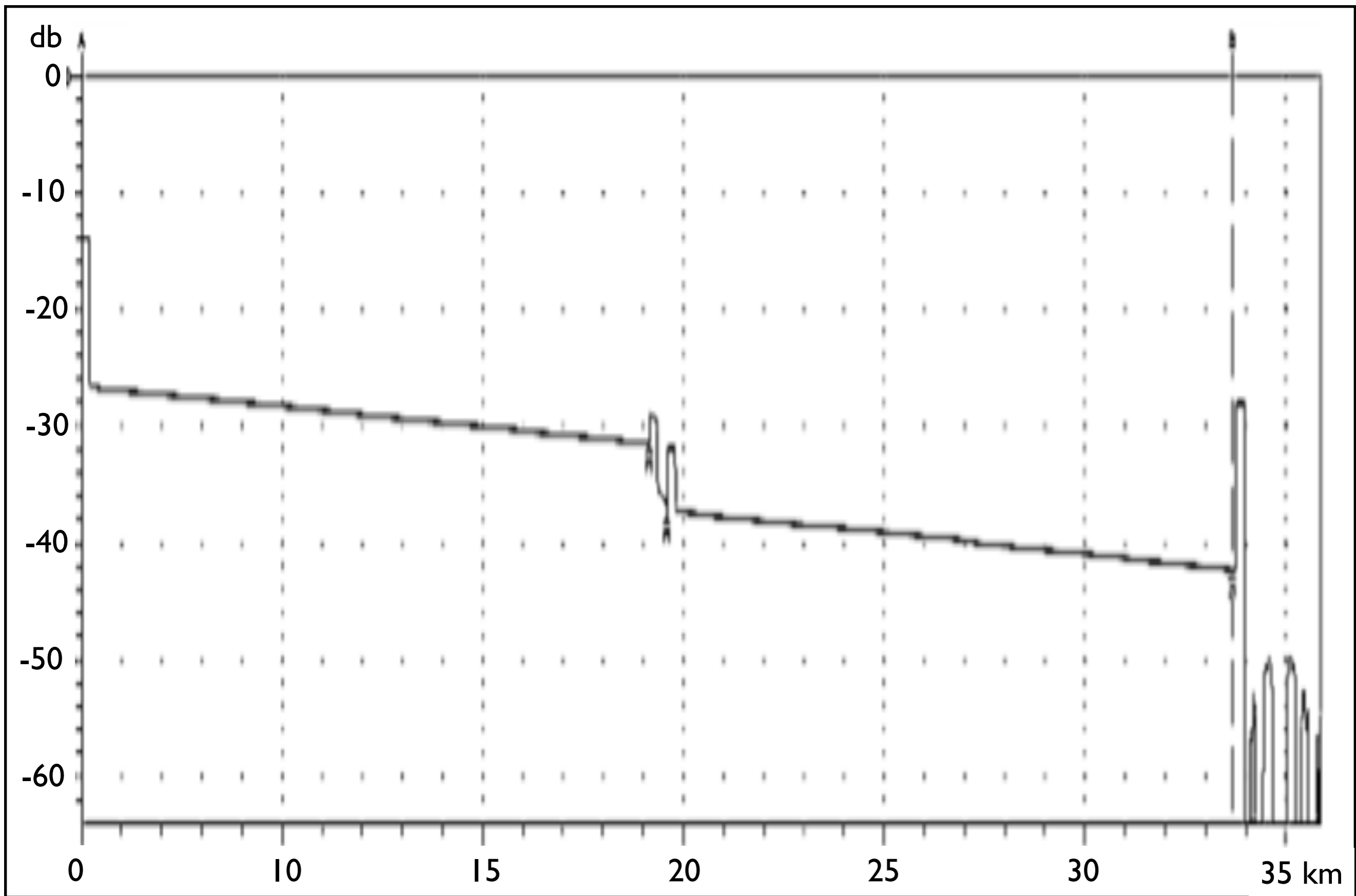


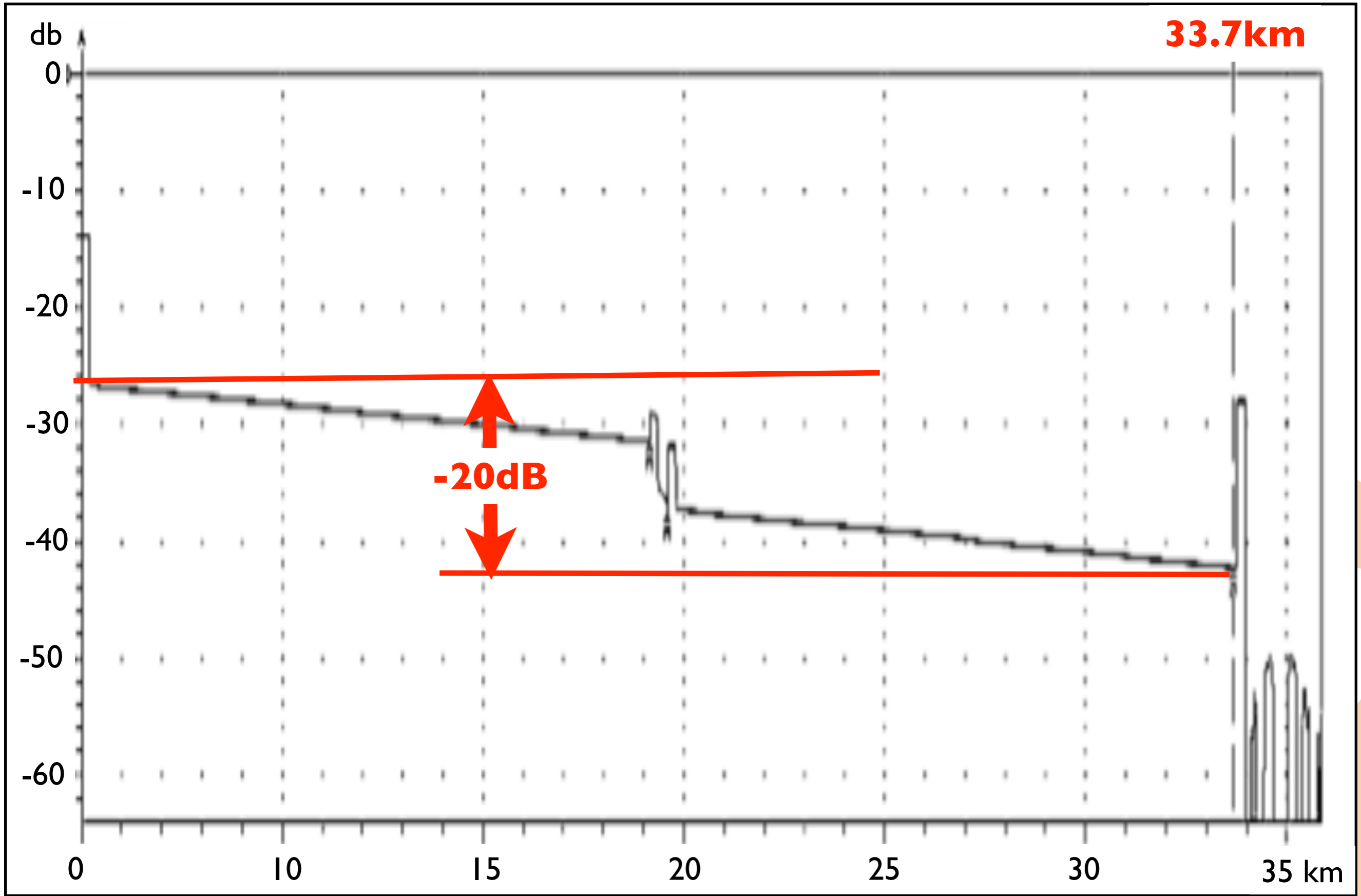
Options

- LR-4 (O-band) is the only option.
 - Only type (band) that can be amplified.
 - 0 material dispersion.
- Semiconductor Optical Amplifiers (SOAs)
 - As component available for all bands.
 - Much much cheaper than PDFAs.
 - We had one for the O-Band.

Experiment

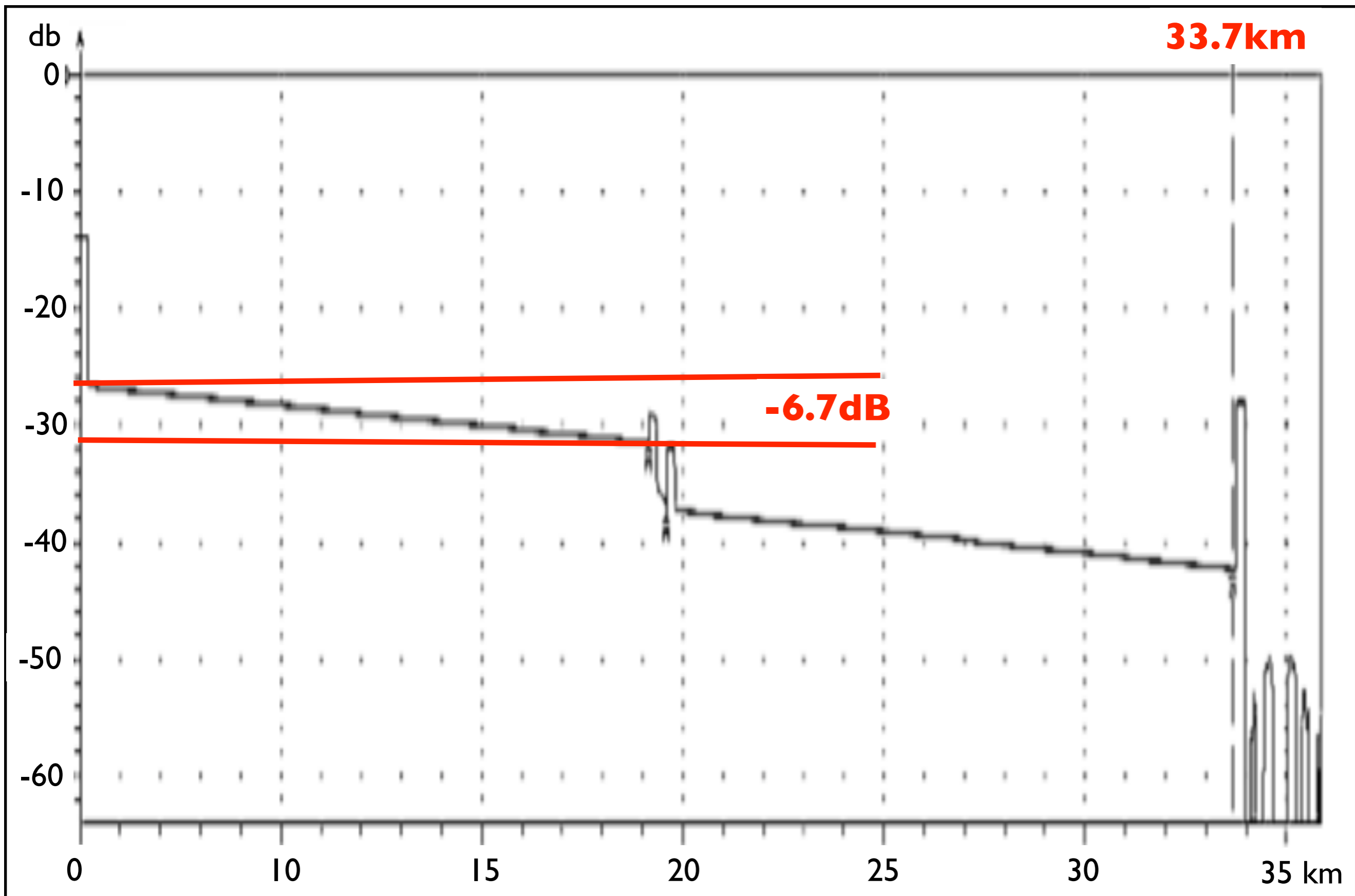


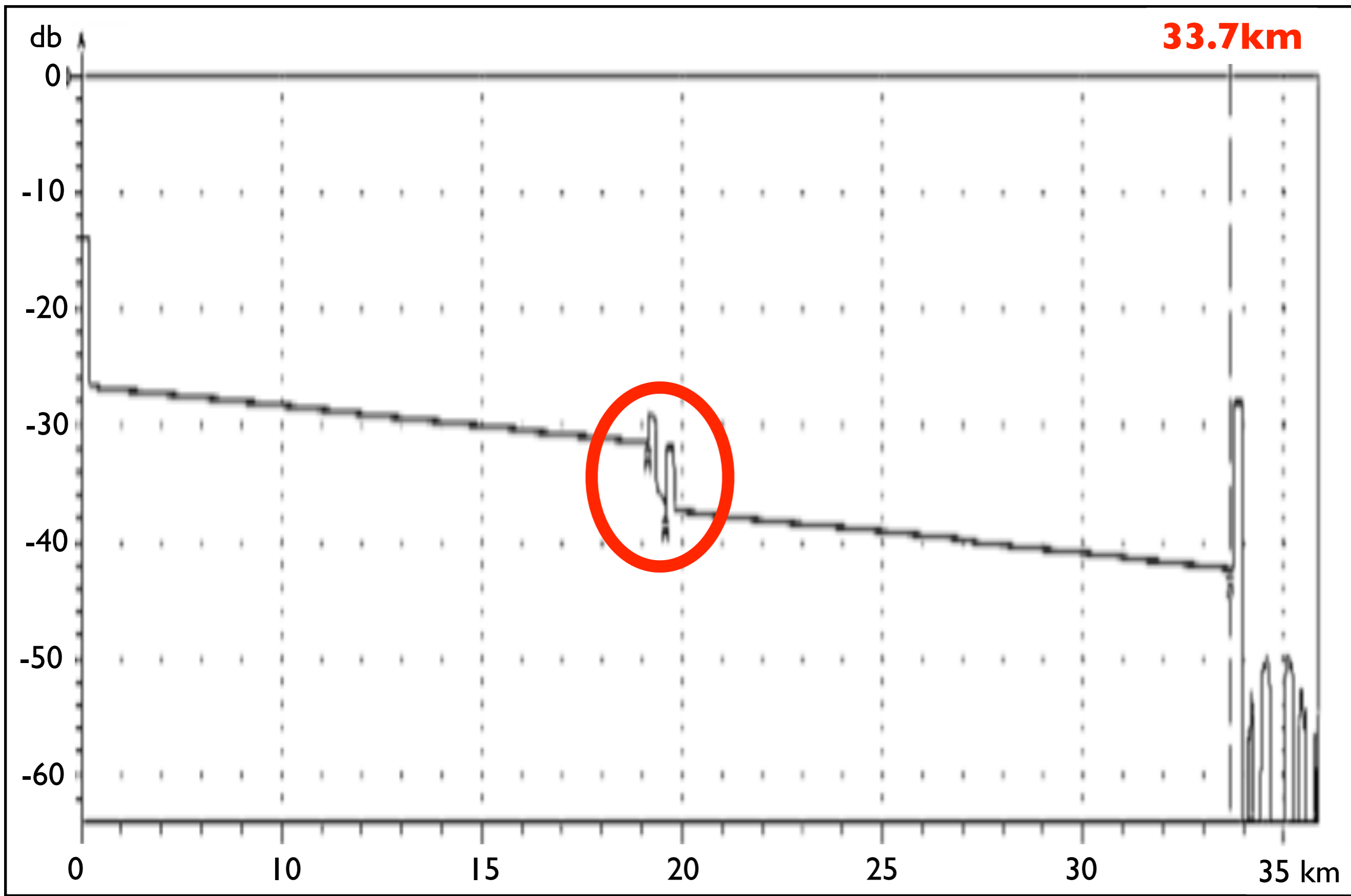


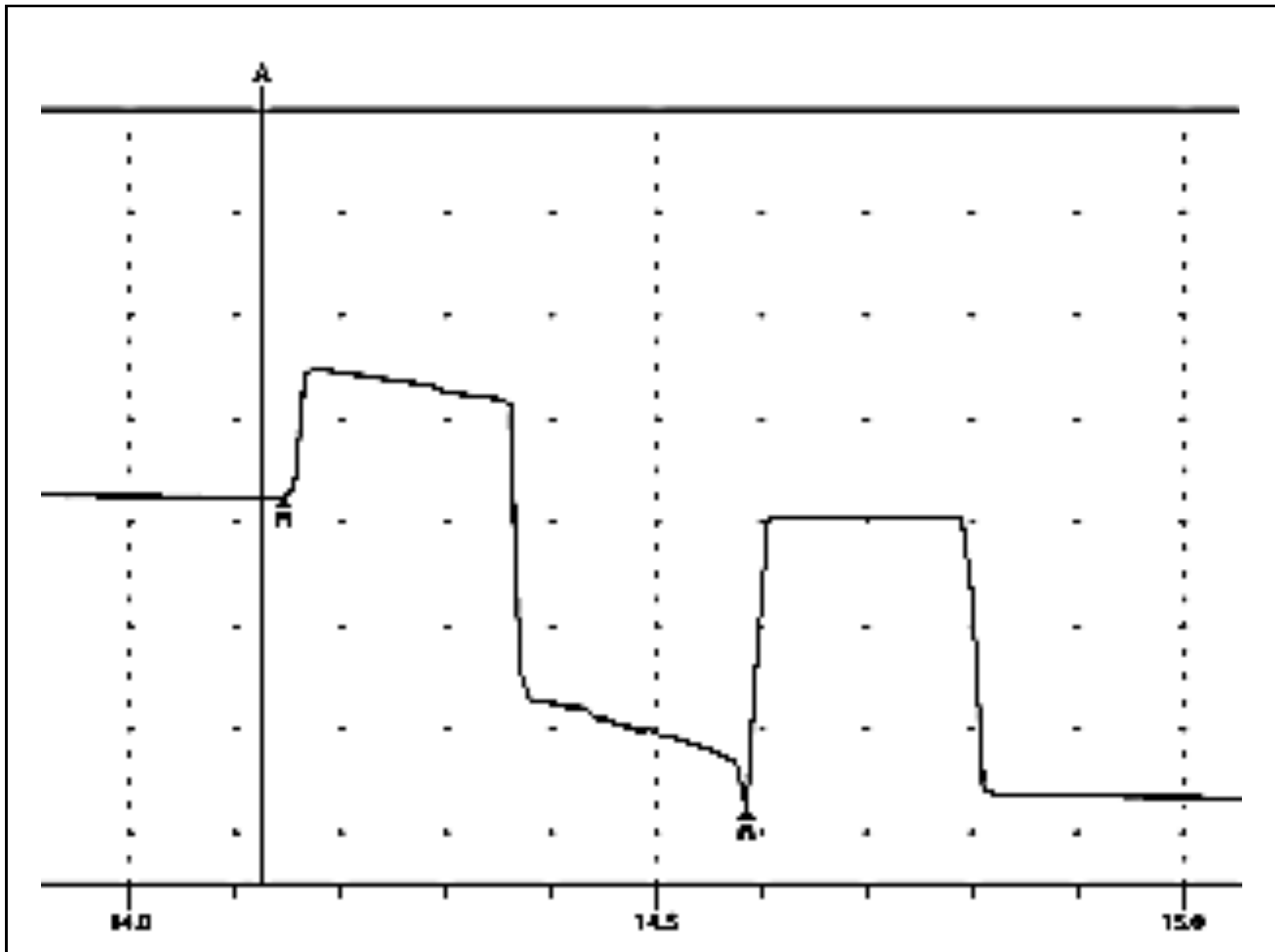


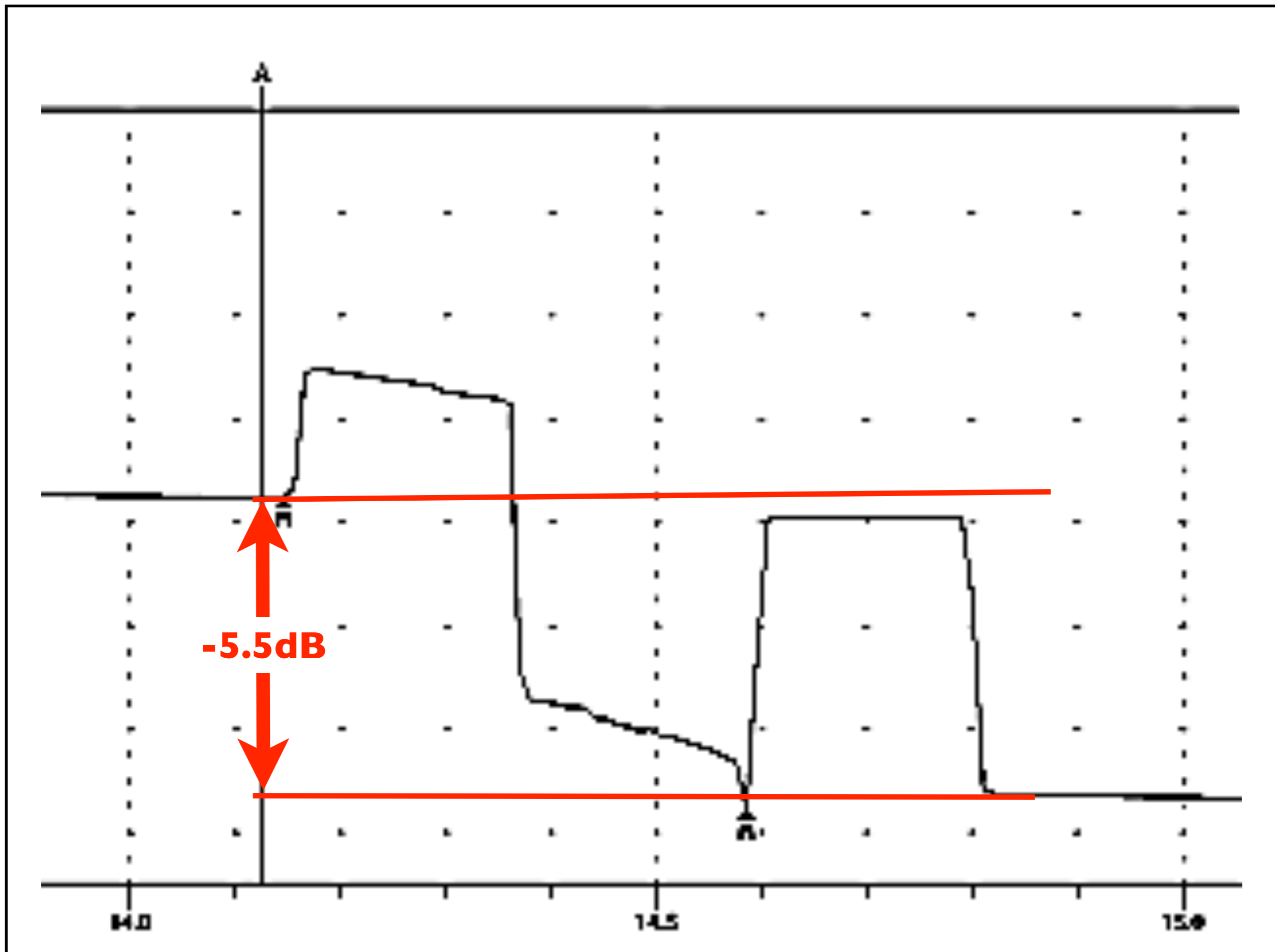
33.7km

-20dB









Result

- 6 trillion, 500 billion frames
(6,500,000,000,000)
- Receives, all - 2
(6,499,999,999,998)



Conclusions

- Doped Fibre Amplifiers only suitable for O-band.
 - PDFA
- Semiconductor Optical Amplifier.
 - Seems to work well for the O-band.
 - No ready made appliance
(Just components and evaluation boards or lab equipment).

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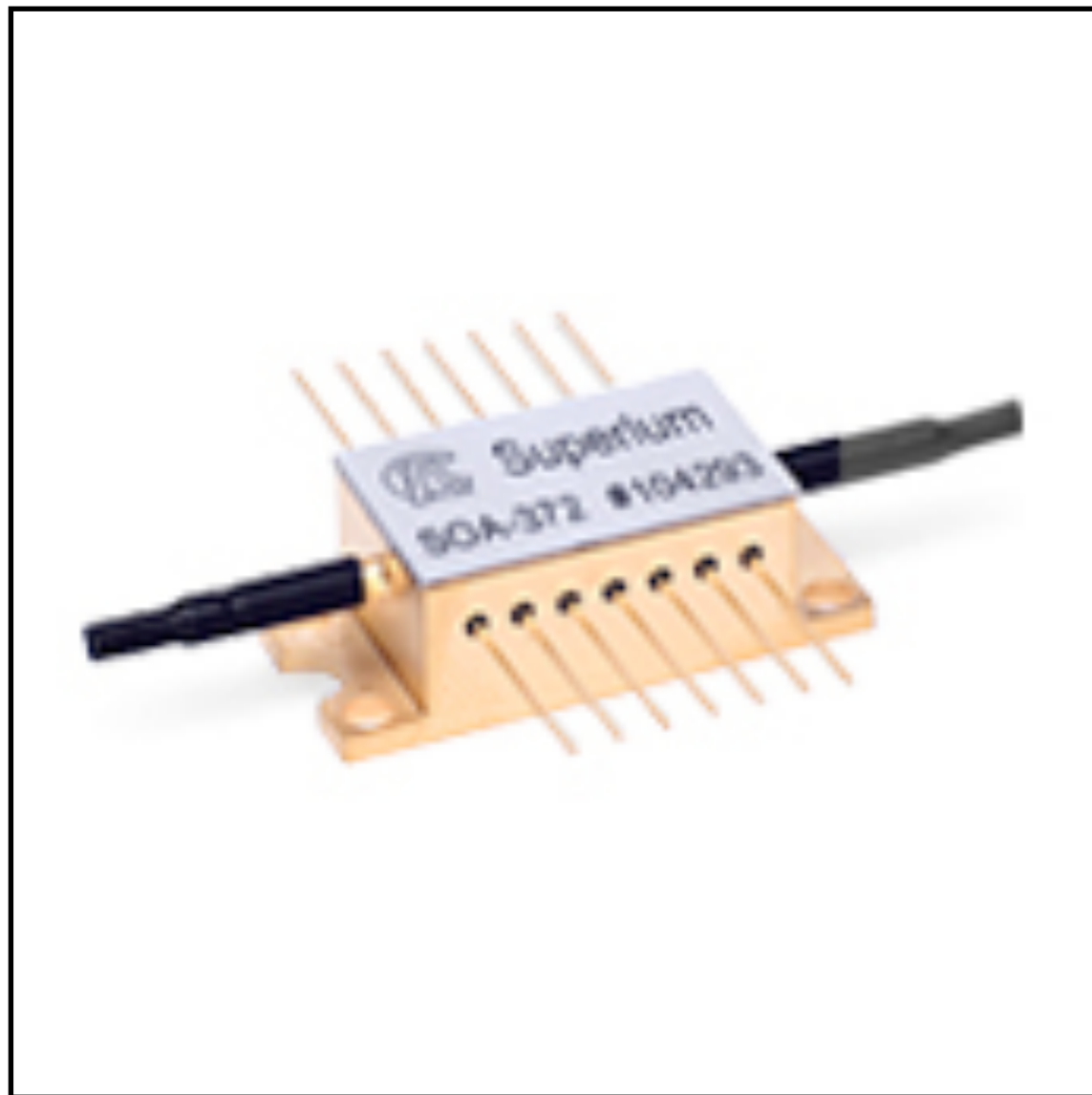


Next steps

- No SOA appliances (November 2011).
- Started to work with vendors and design bureaus to get that changed.
- 40km optics might be around the corner.
 - Q4 2012... from one vendor...
 - Electrical power budget might be a problem.

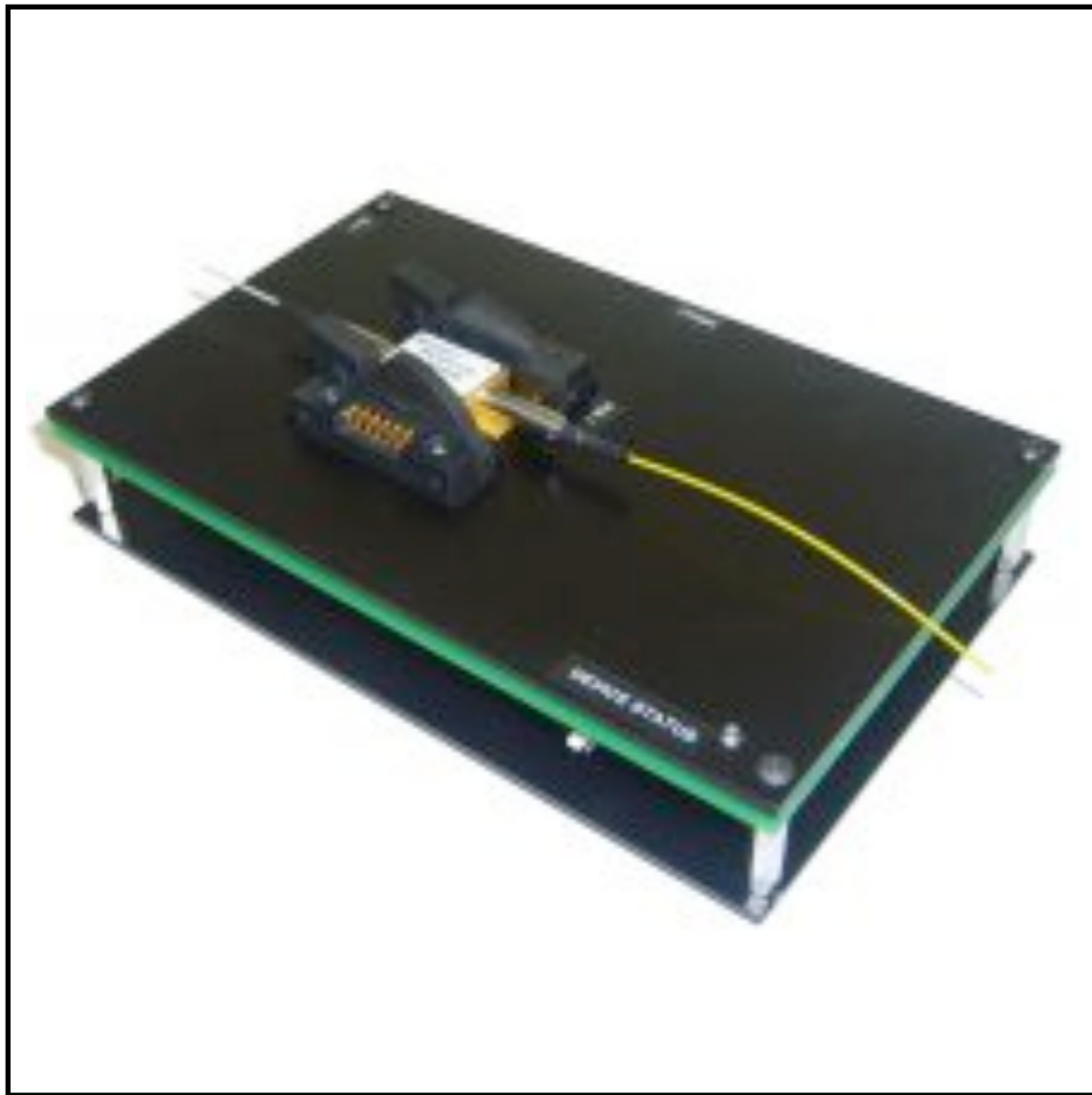
SOA appliance

- We only could find components

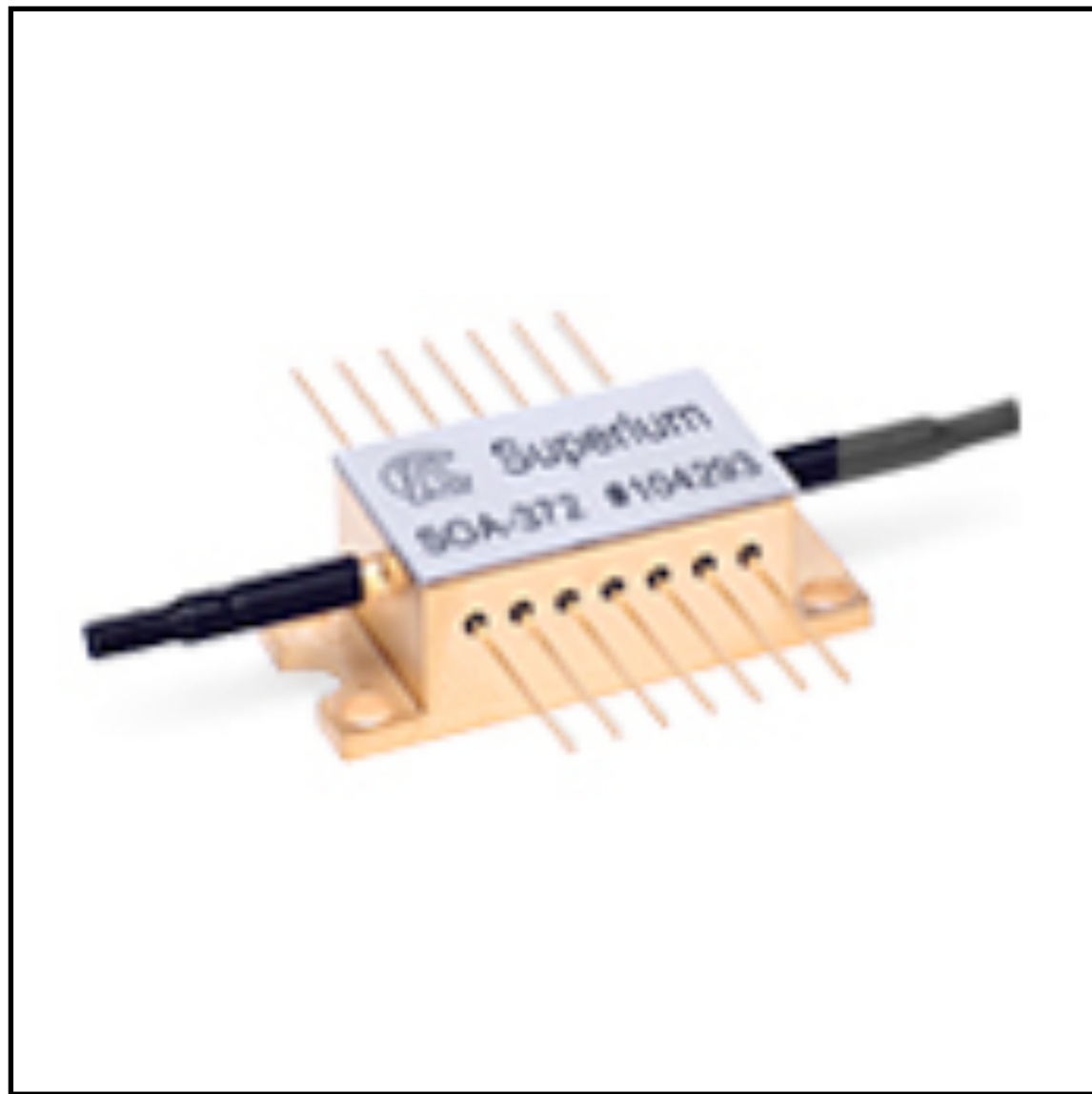


SOA appliance

- We only could find components or lab equipment.



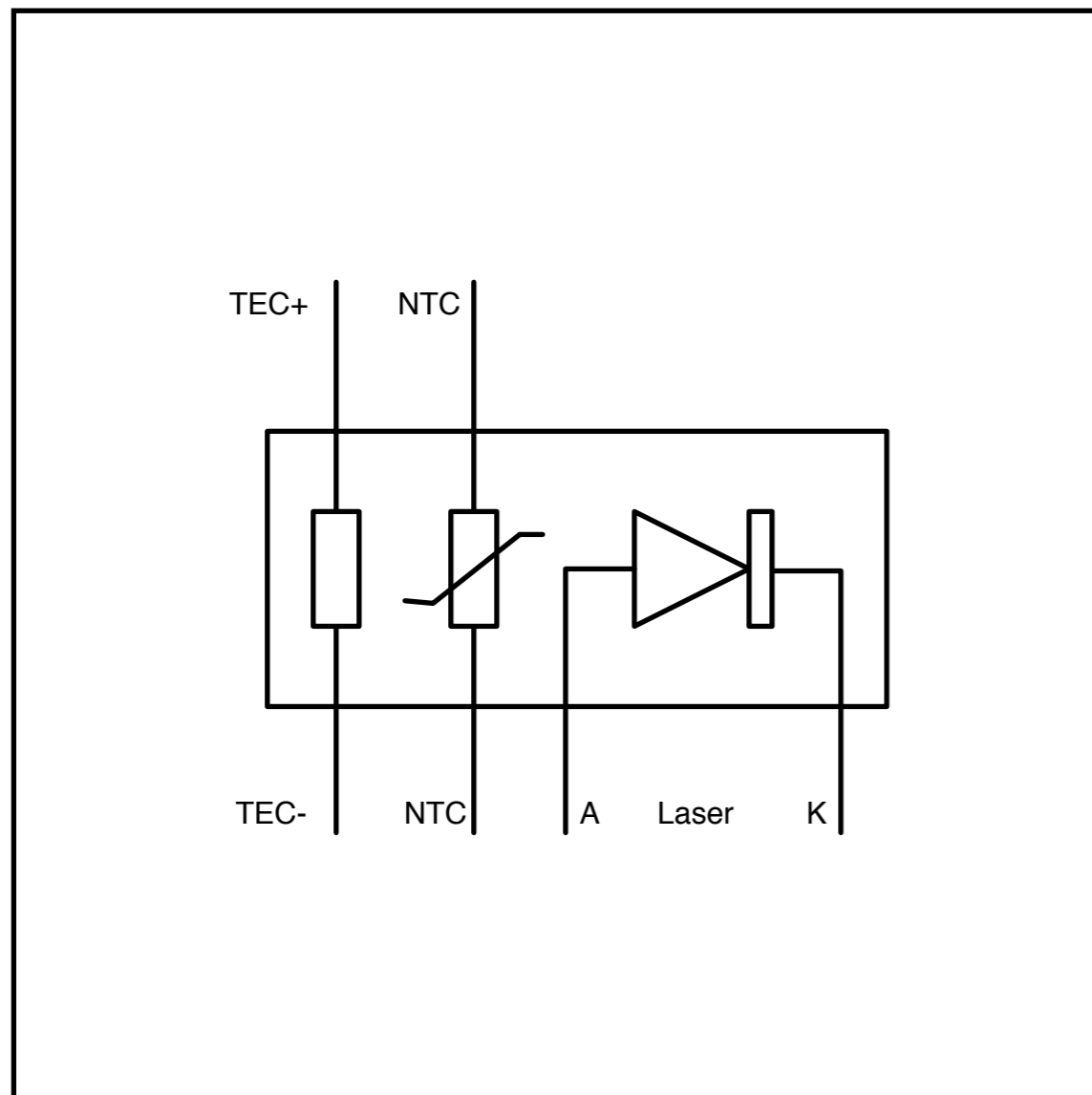
SOA appliance



- We only could find components or lab equipment.
- What is in that component?



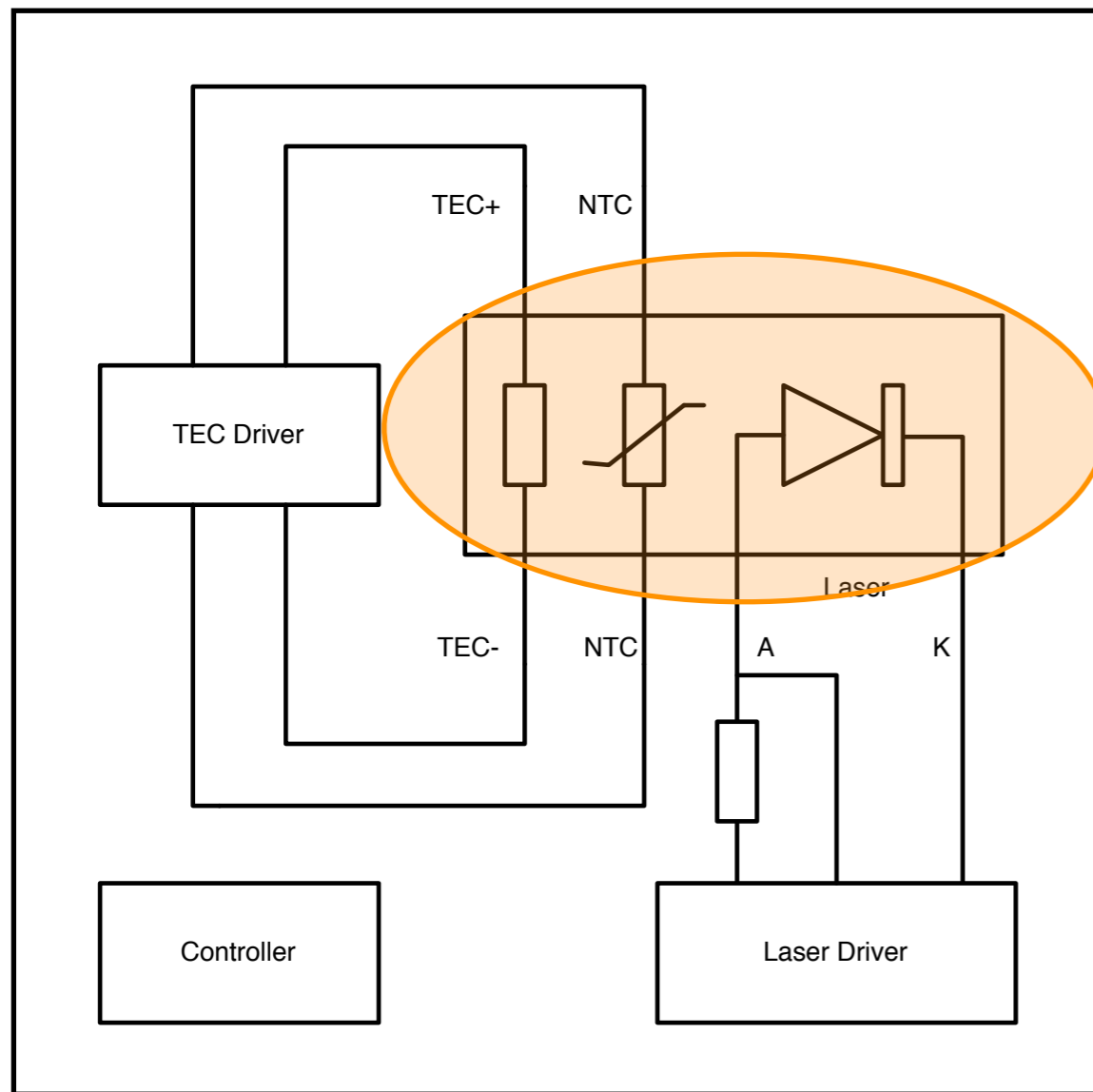
SOA appliance



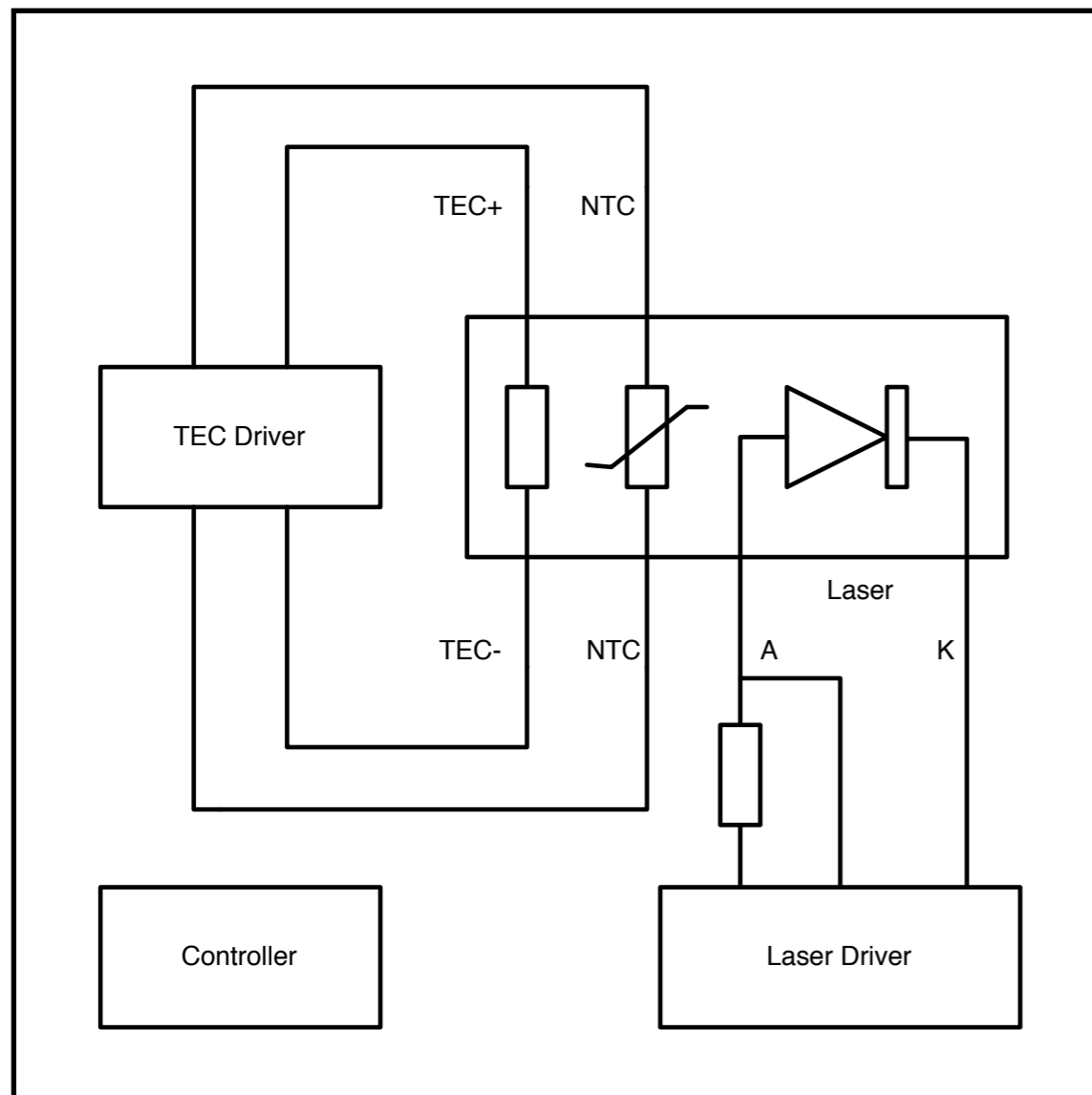
- We only could find components or lab equipment.
- What is in that component?
- SOA consist of three parts.
 - Laser
 - Peltier element (TEC)
 - NTC (temperature sensor)

SOA appliance

- SOA consist of three parts
 - Laser
 - NTC (temperature sensor)
 - Peltier element (TEC)



SOA appliance



- SOA consist of three parts
 - Laser
 - NTC (temperature sensor)
 - Peltier element (TEC)
- SOA appliance
 - TEC driver to keep the temperature constant.
 - Feedback loop.
 - Laser driver to control the current through the laser.
 - Feedback loop.
 - Controller

SOA appliances

- Cube optics built an SOA appliance
 - IU 19" rack mountable appliance
 - Dual power supply
 - Web interface
- Available today (with a delivery time)

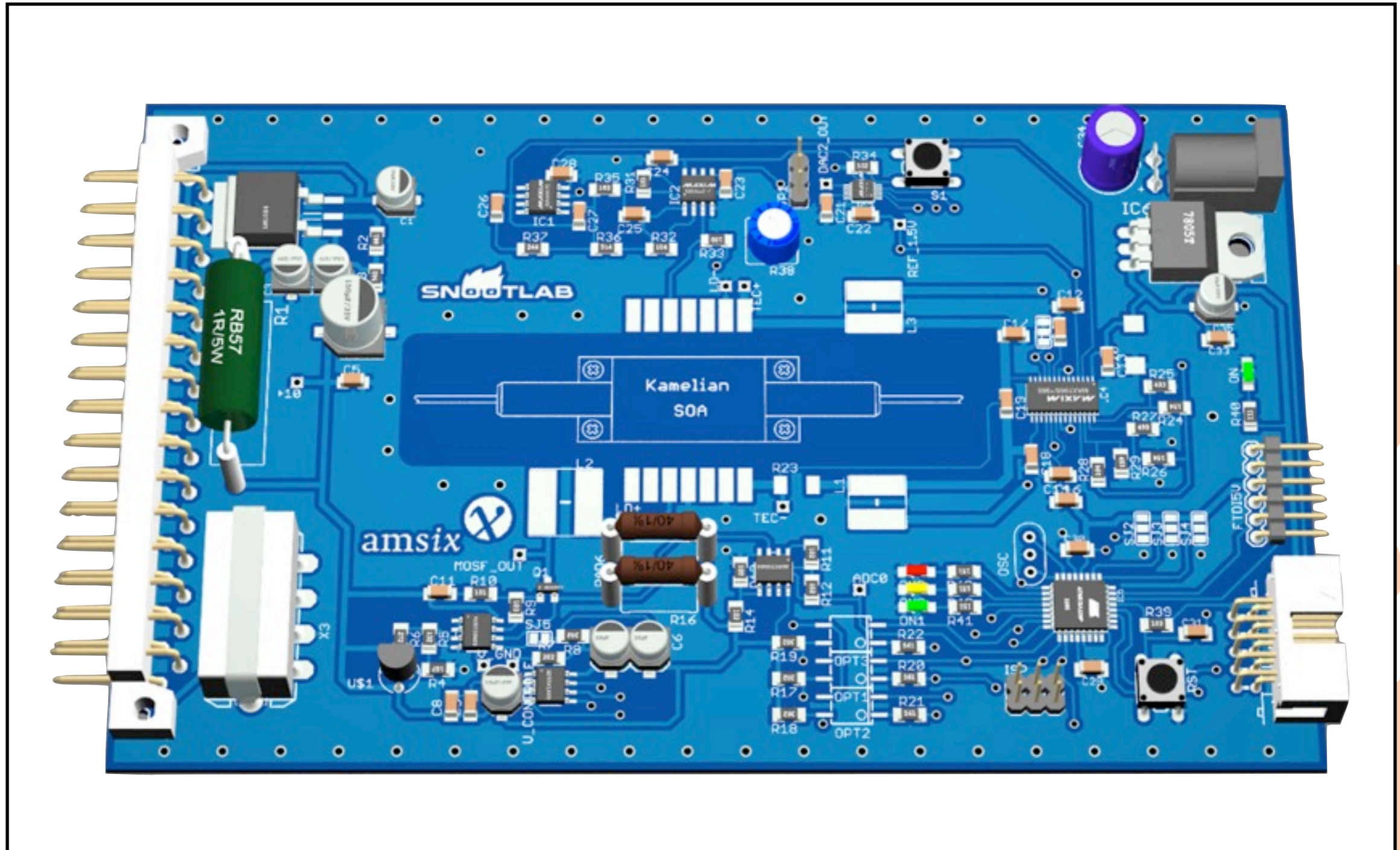


SOA appliances

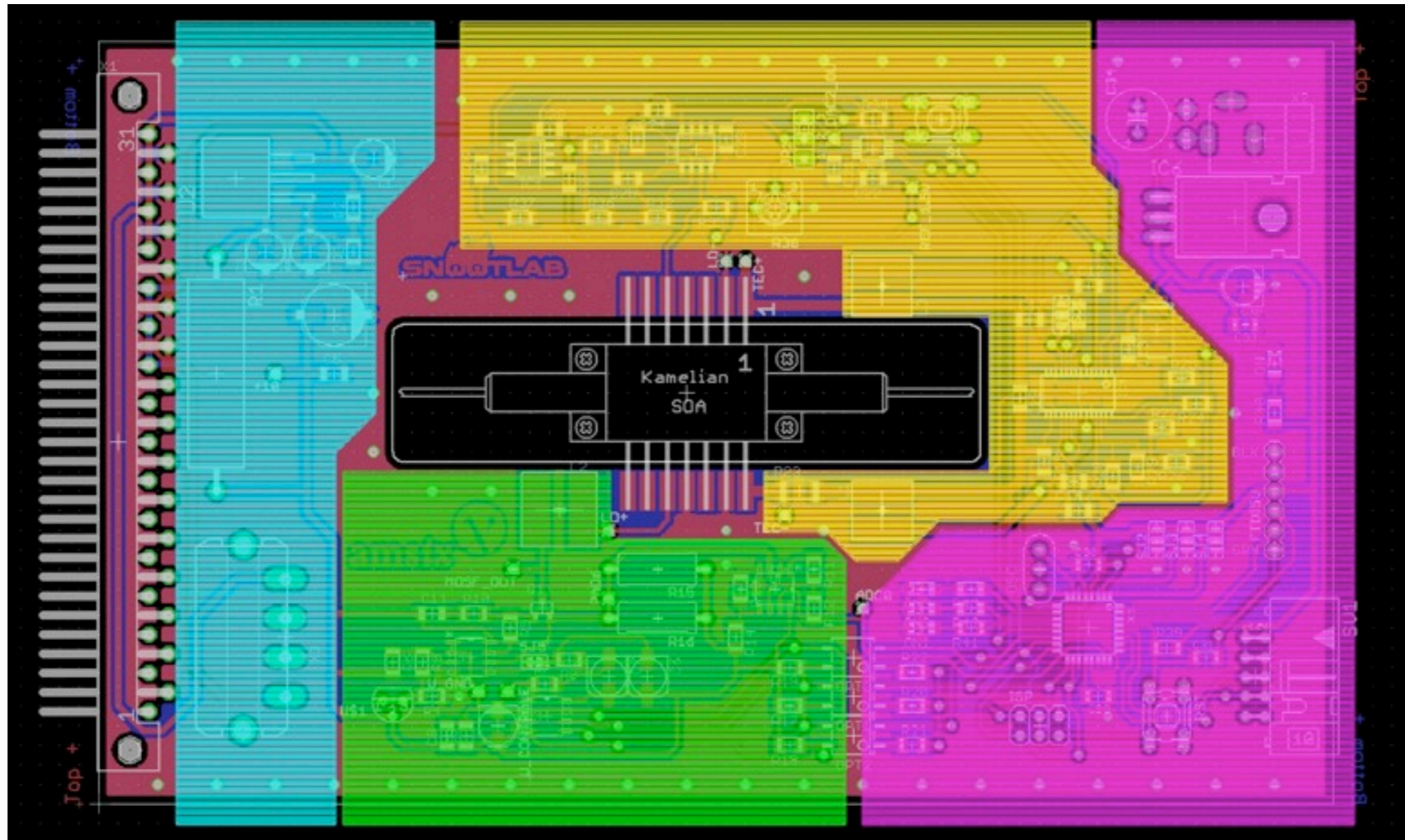
- SnootLab
 - 3U for a rack of 8 SOAs
 - Covega or Amphotonics (Kamelian)
 - Dual power supply
 - SNMP interface
 - Open Hardware
 - contact@snootlab.com



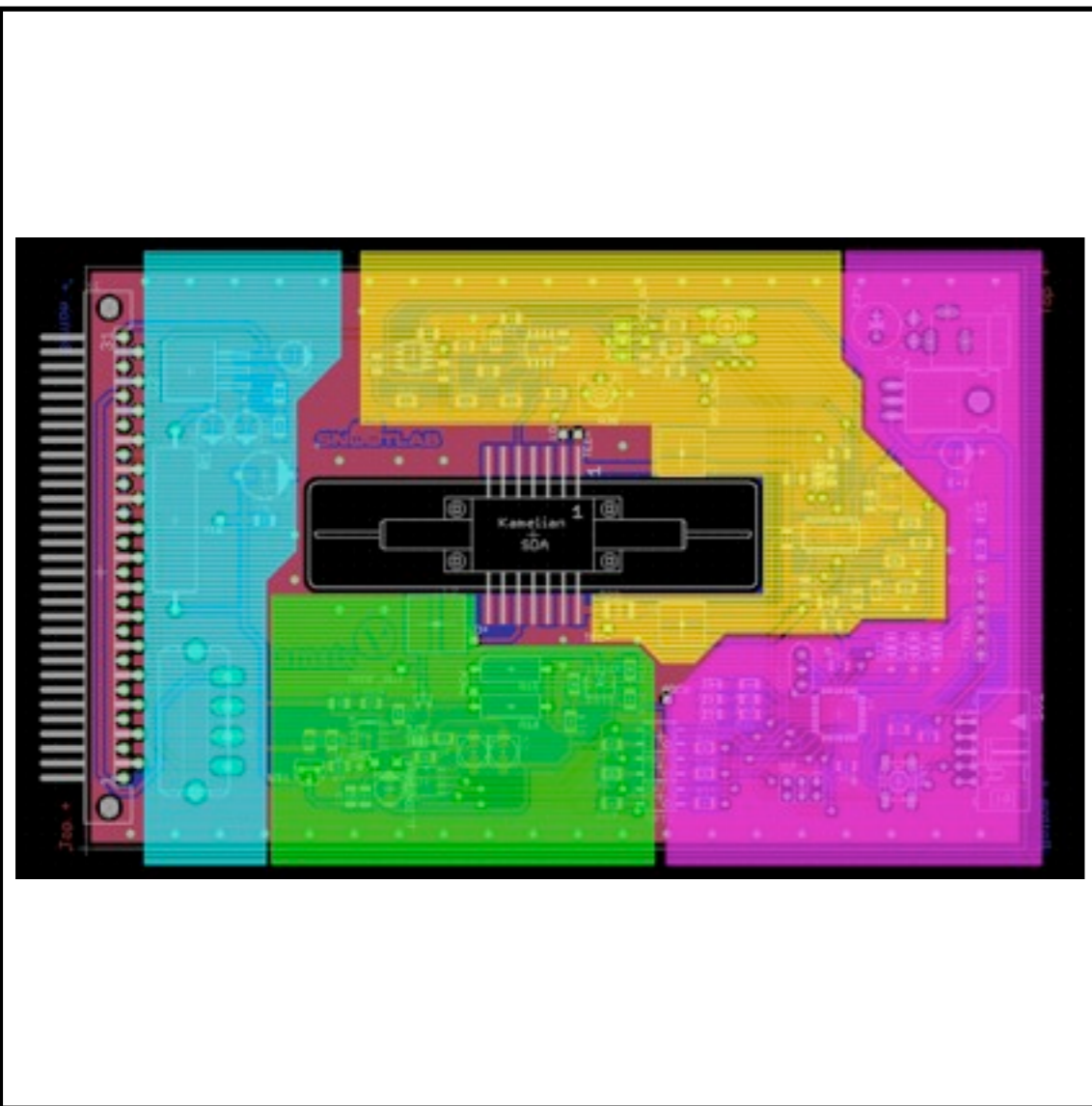
1st Prototype



2nd Design



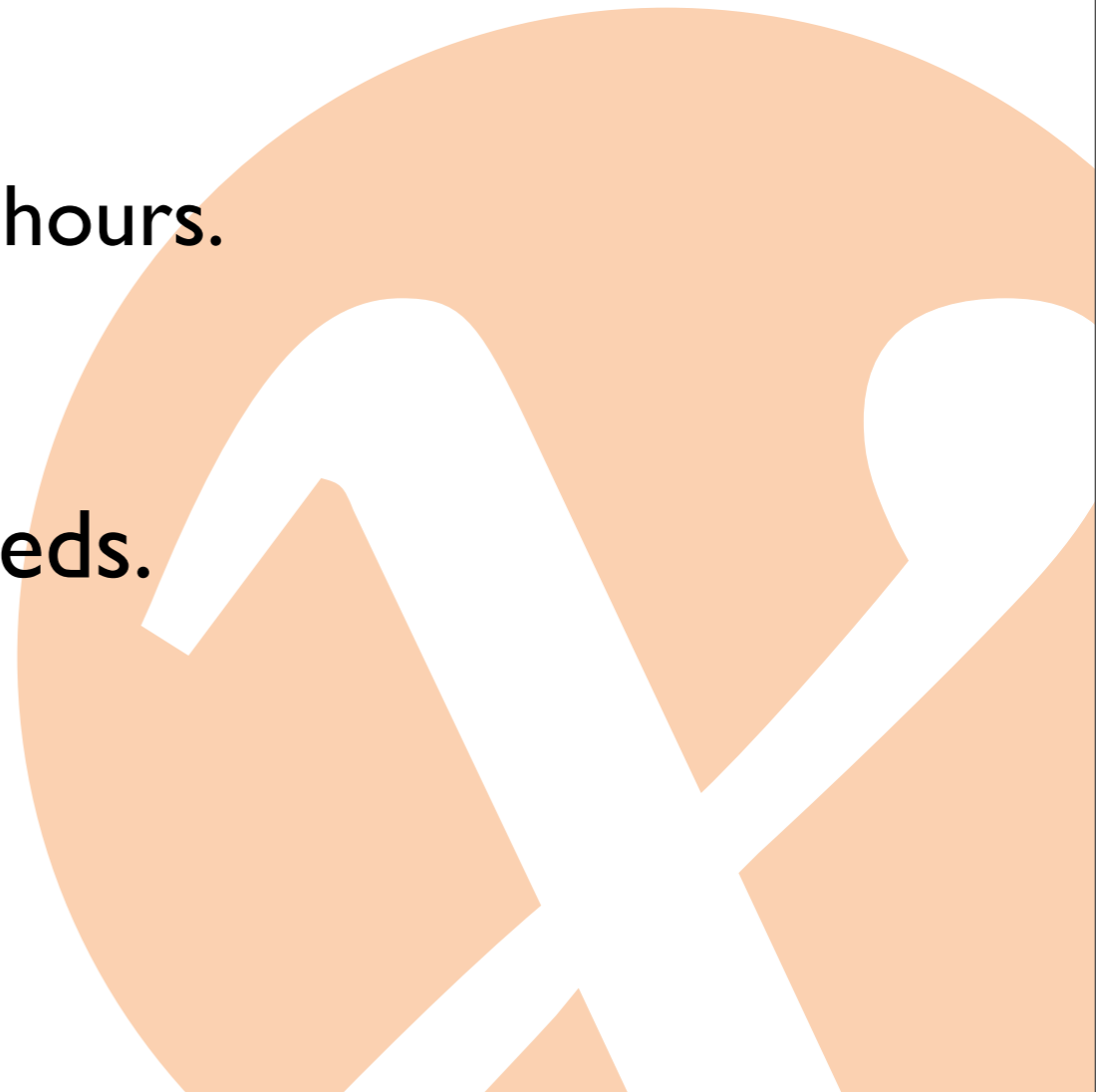
2nd Design



- Blue the power management.
- Yellow : the TEC (Peltier) management.
- Green: the Laser driver.
- Pink : the "arduino".
 - Controller.
 - The LED power management.
- Multi vendor:
 - Amphotronics (Kamelian).
 - ThorLabs (Covega).

Test results

- Cube optics
 - Error free over 22.6 km over 96 hours.
- SnootLabs
 - Error free over 22.6 km over 36 hours.
 - Shorter test window.
- This is suitable for most of our needs.



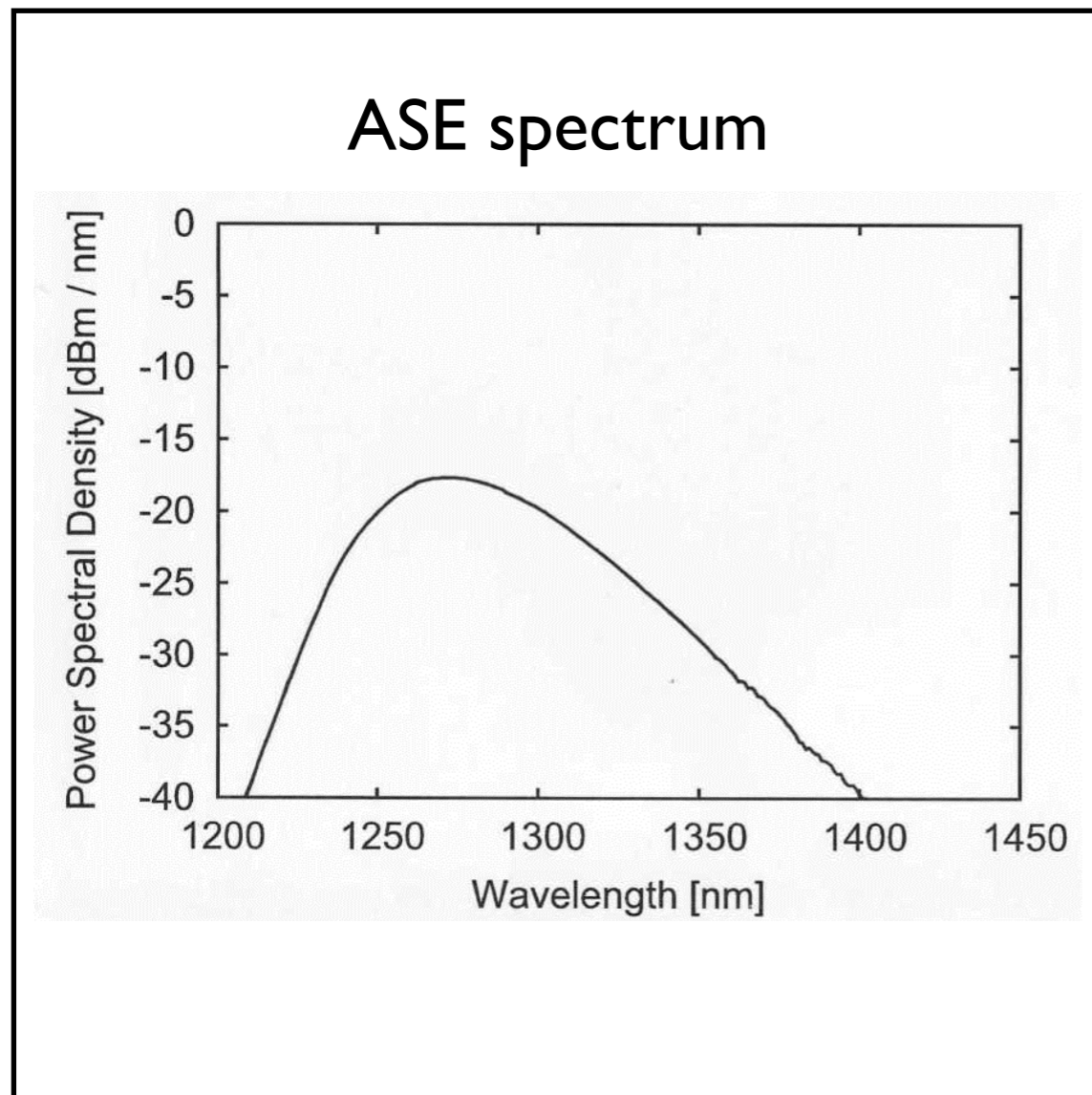
Test results

- Not error free over 45 km.
 - Both Cube optics and SnootLab's 1st prototype.
 - Might be too long.
 - Dispersion?
 - Extinction ratio
 - Ratio between 0 and 1 levels.
 - Amplifier might not amplify these levels equally.
- Noise?



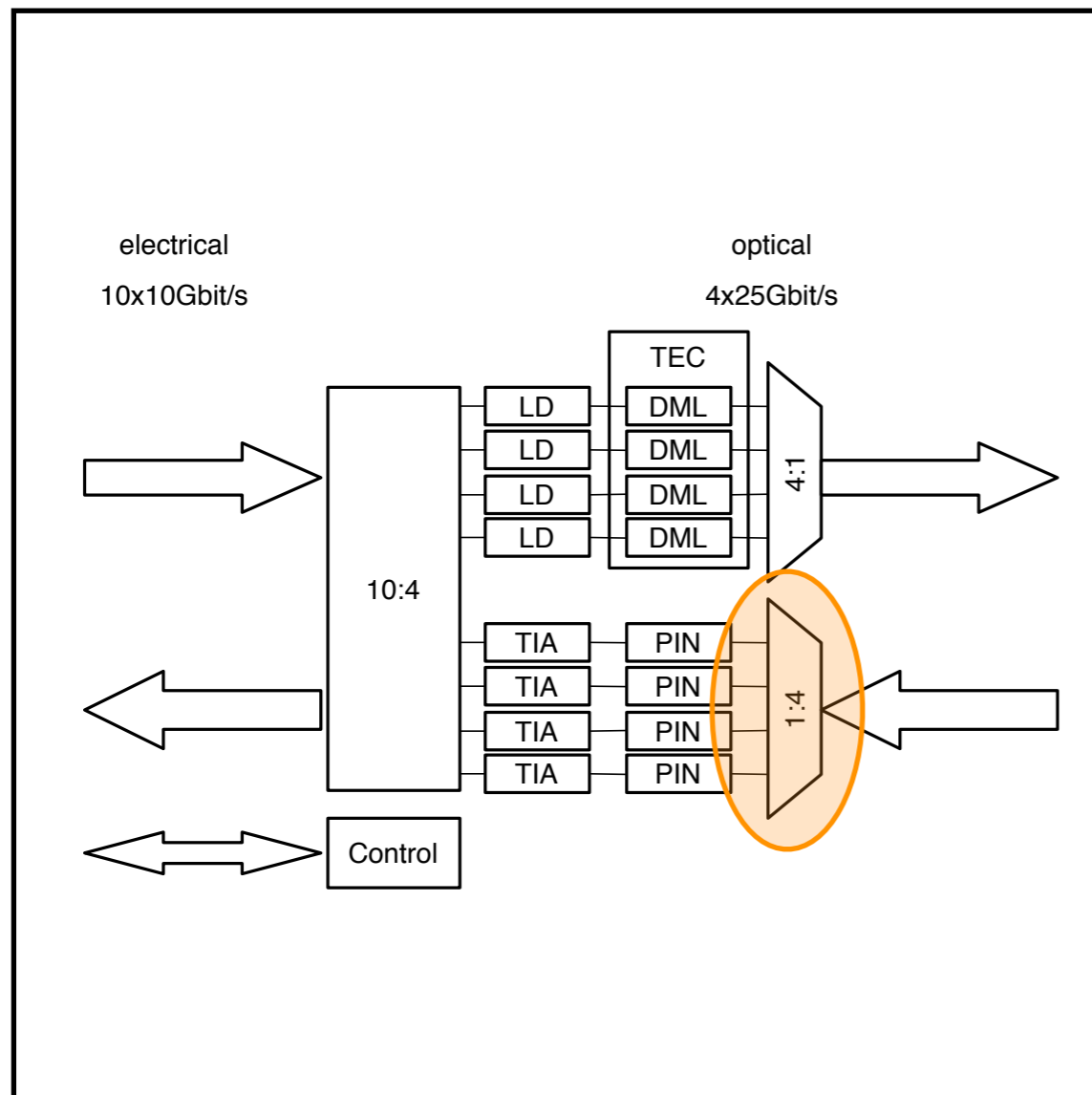
Noise

- Amplified Spontaneous Emission (ASE)

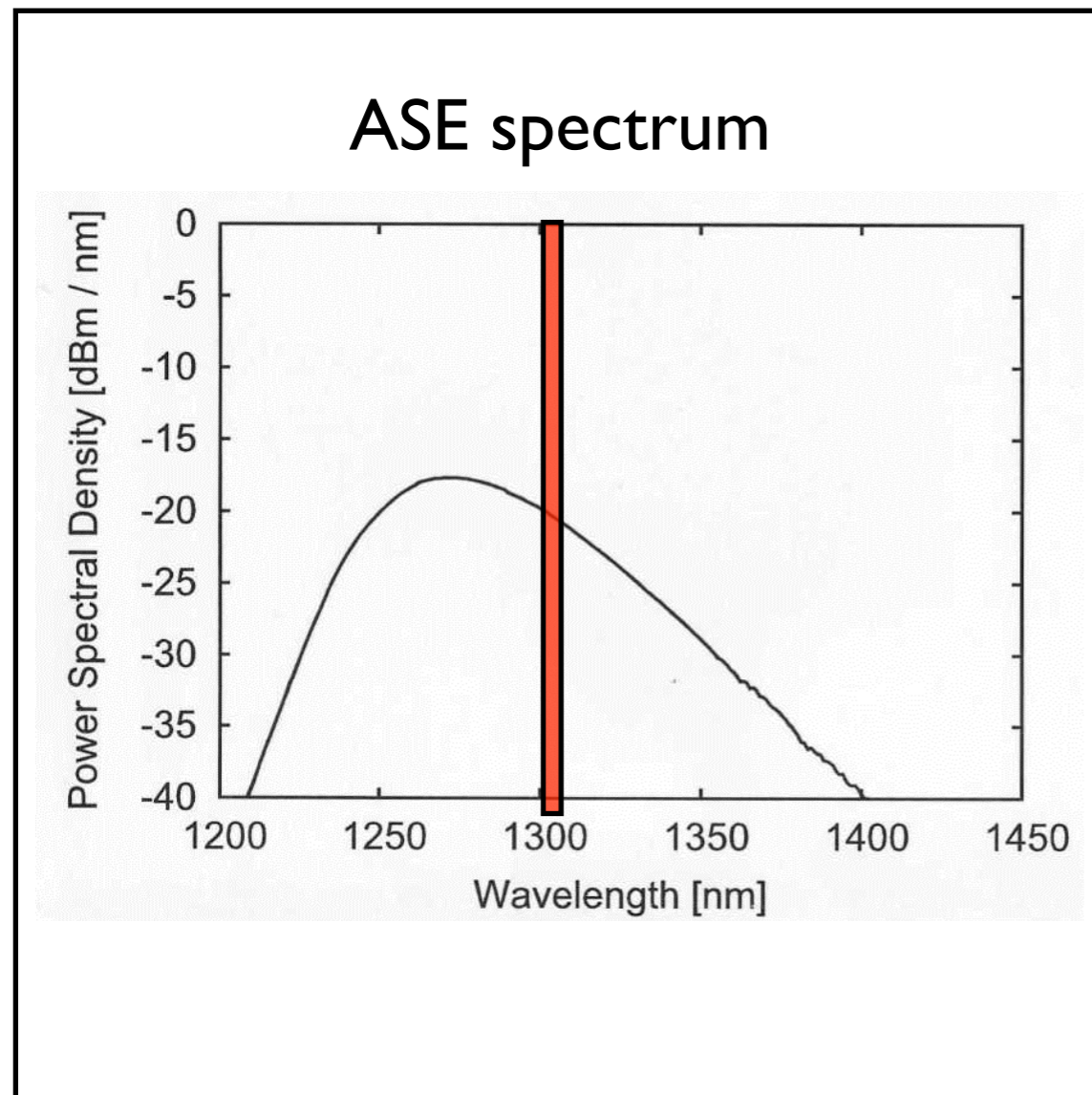


Noise

- 100G-LR receivers
- LAN WDM filter in the receiver drops most of the noise spectrum.



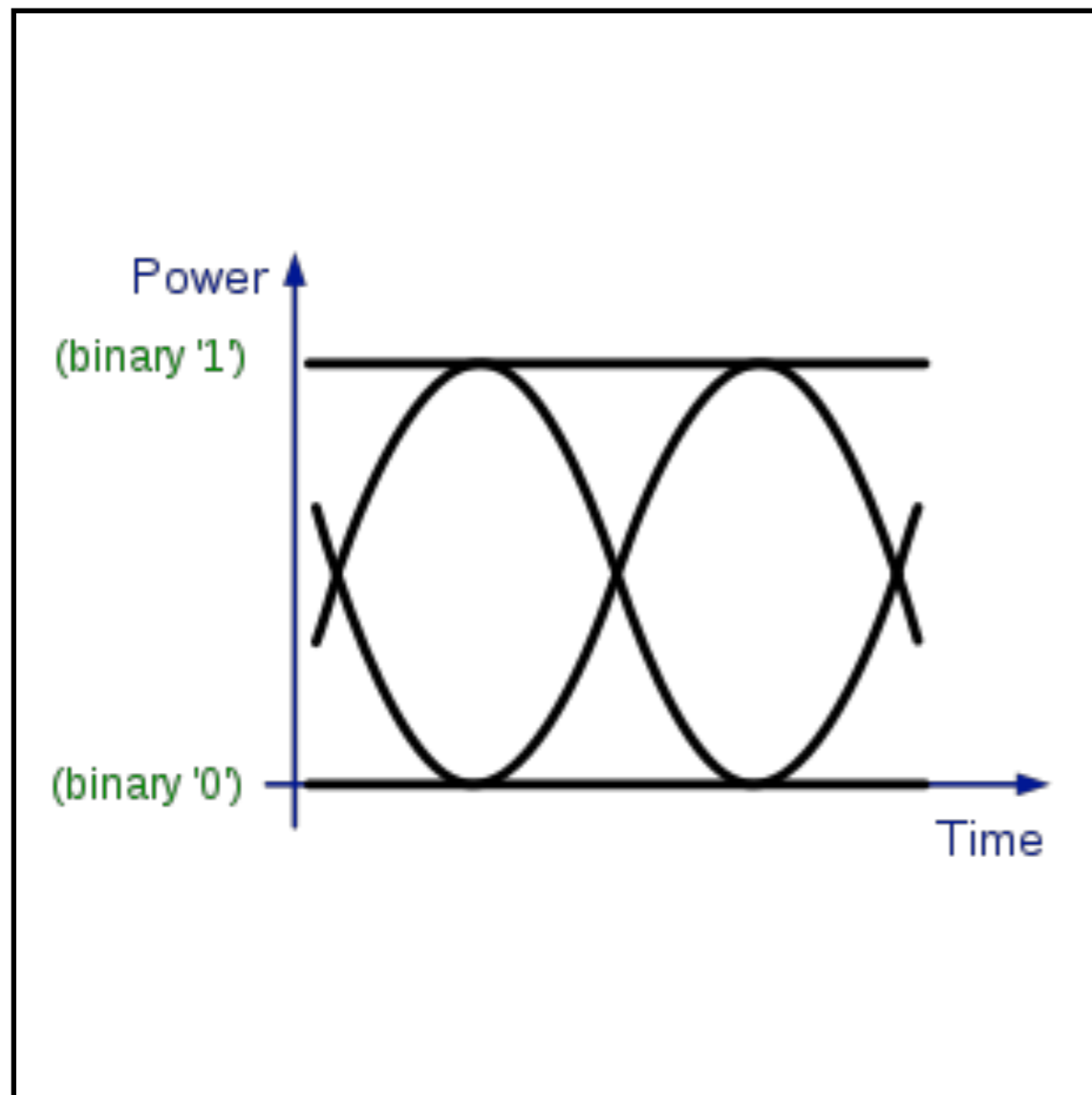
Noise



- Amplified Spontaneous Emission (ASE)
- LAN WDM filter in the receiver drops most of the noise spectrum.
- Noise should be suppressed by 40dB to the signal.

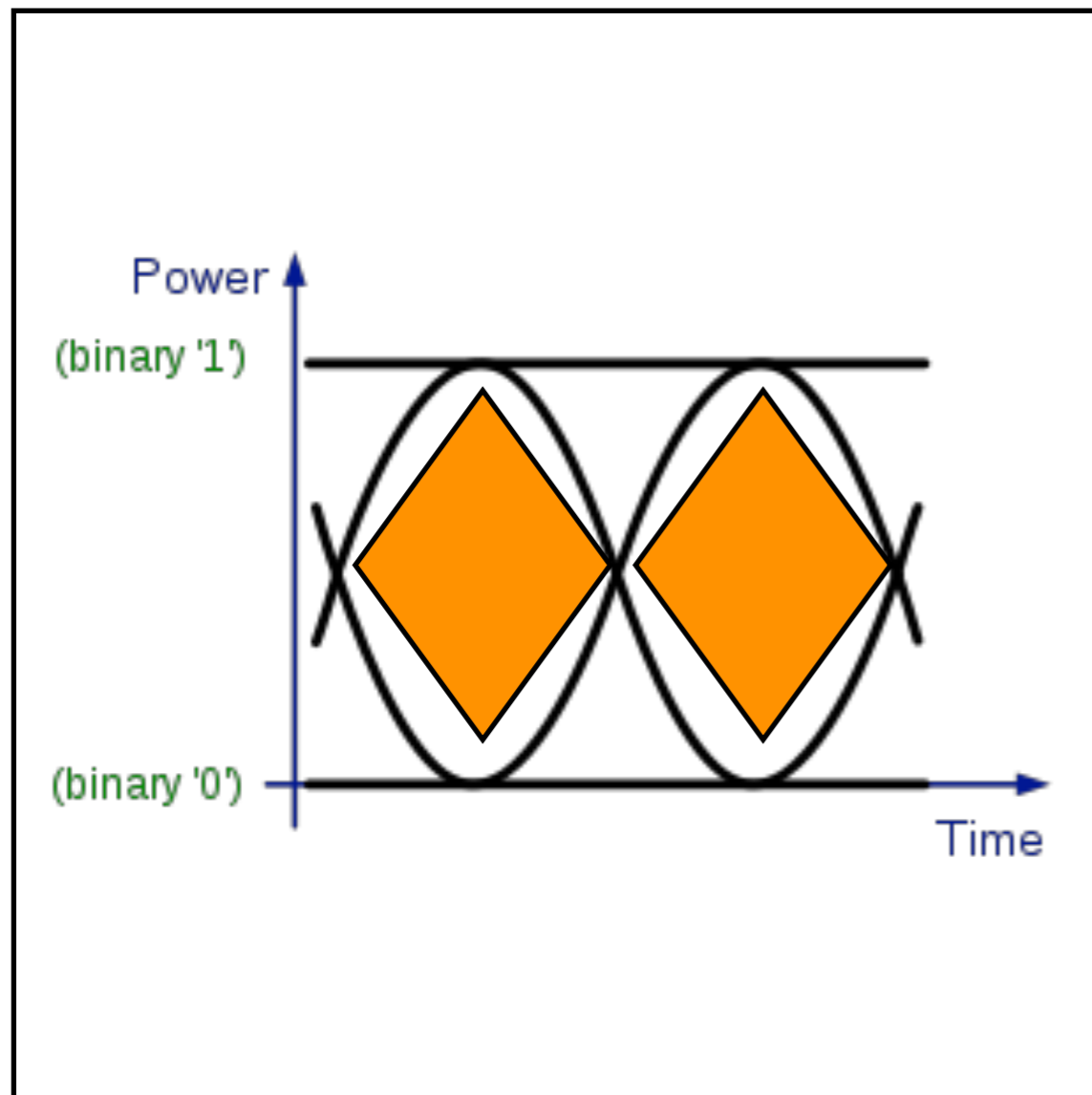
Extinction ratio

- Difference between 0 and 1 level.

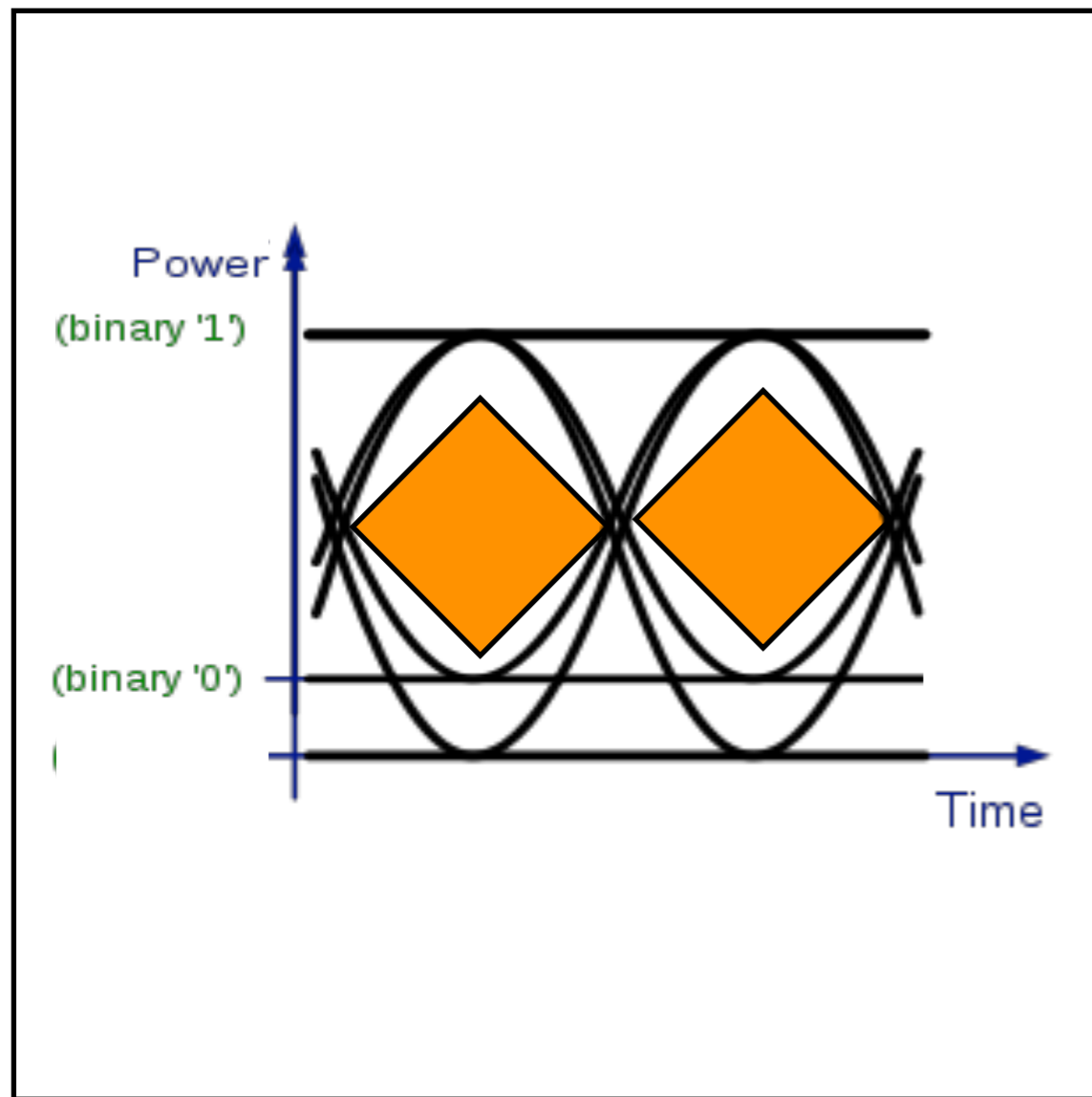


Extinction ratio

- Difference between 0 and 1 level.
- Eye pattern

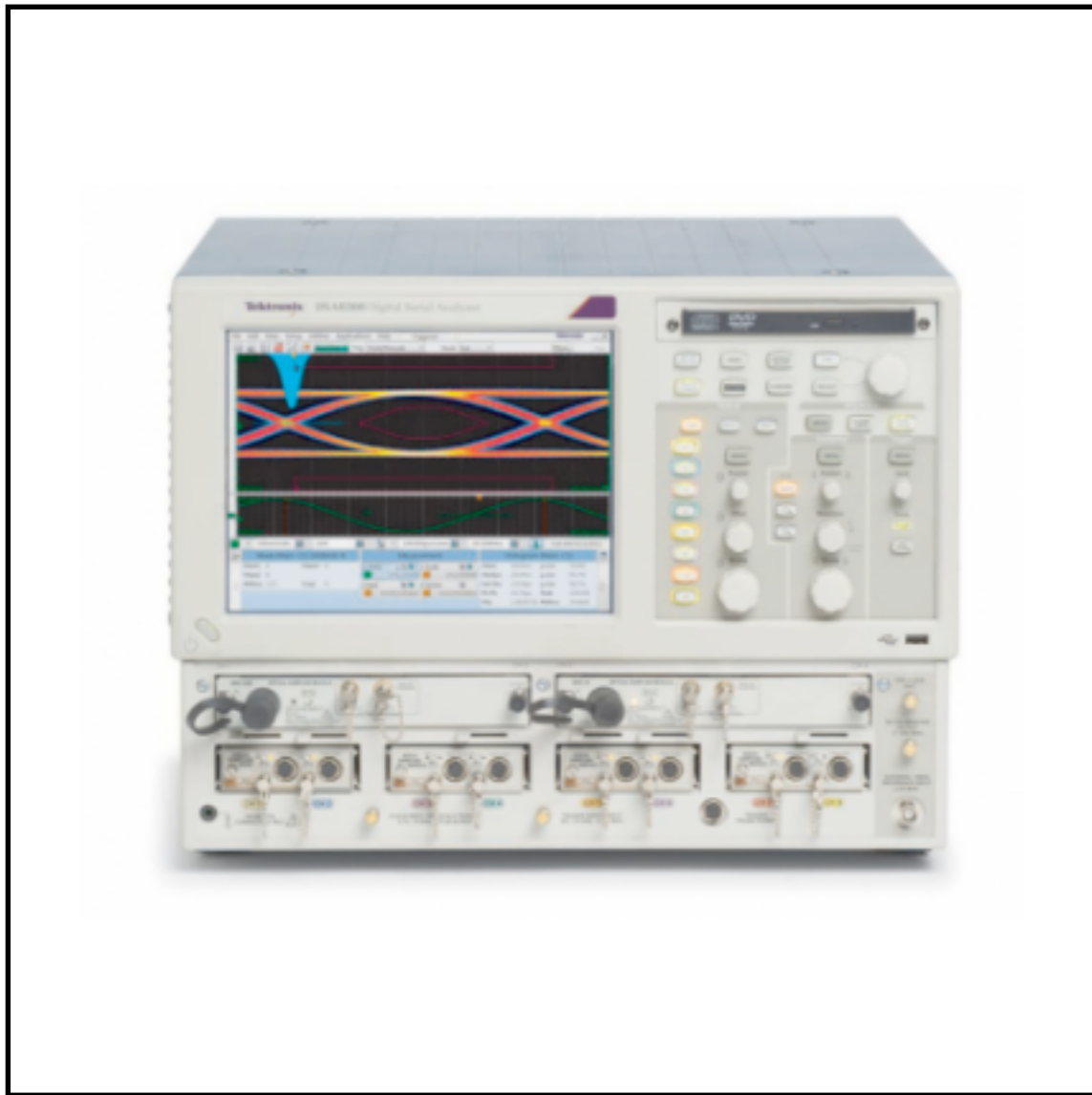


Extinction ratio



- Difference between 0 and 1 level.
- Eye pattern
- 0 Level might be amplified more than the 1 level.
- Unlikely considering the low currents.

Extinction ratio



- Difference between 0 and 1 level.
- Eye pattern
- 0 Level might be amplified more than the 1 level.
- Unlikely considering the low currents.
- We don't have the equipment to see this.
 - Tektronix DSA8300
 - 80C10B module

Conclusion

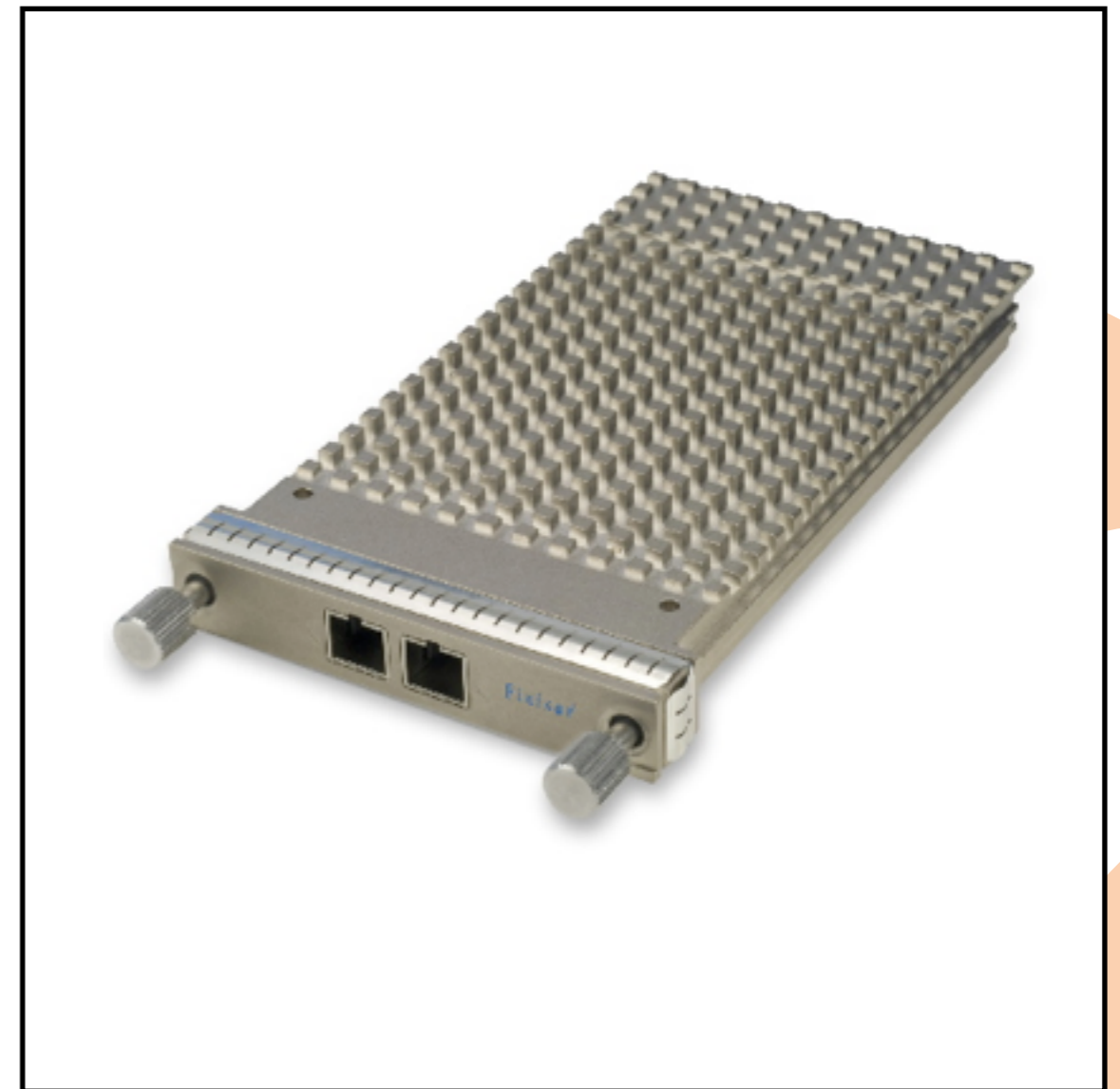
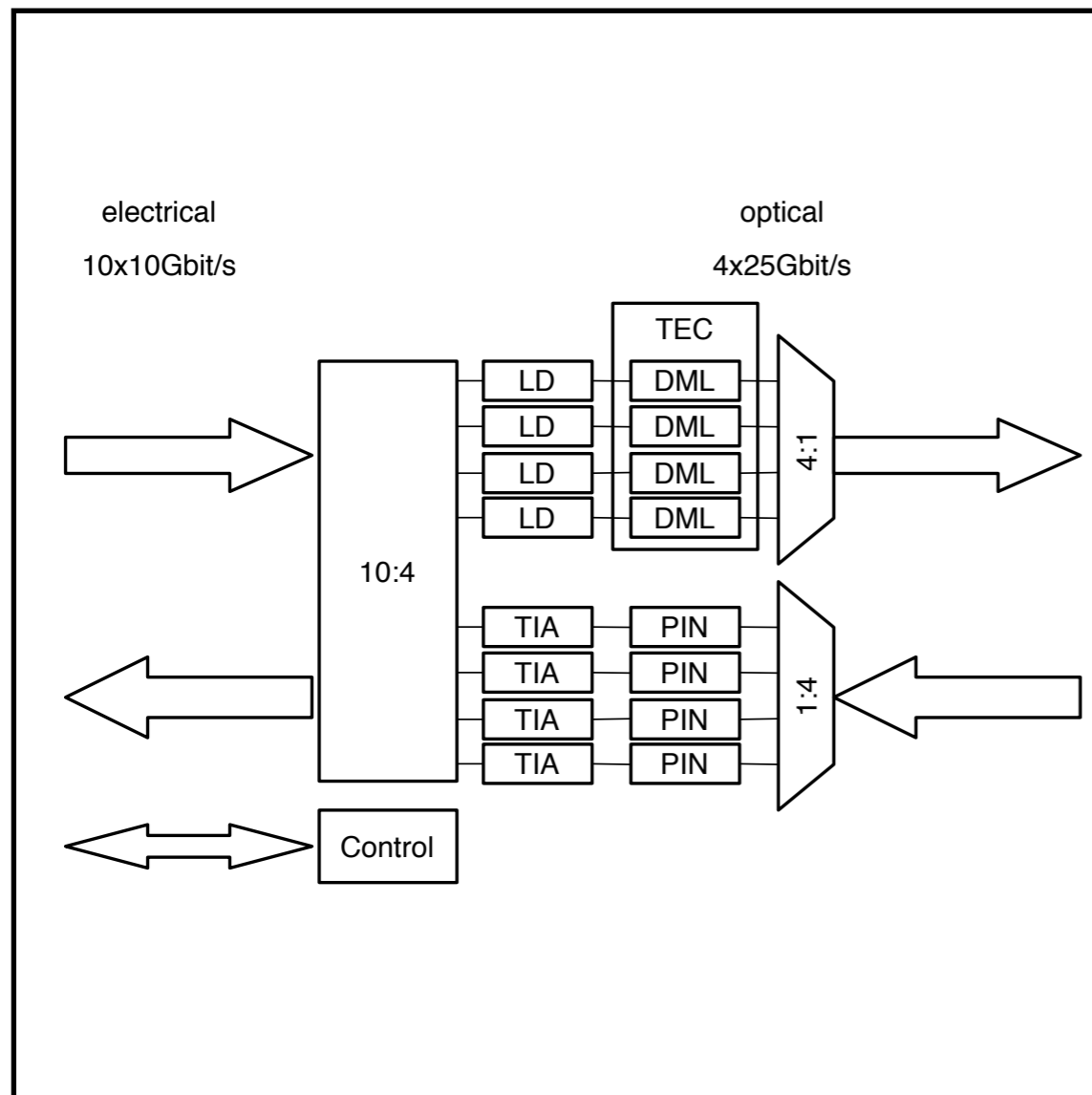
- SOA and PDFA
 - Certainly suitable for ~ 25km ranges
 - Errors on 45km
 - Not sure where they come from yet.
 - Transmission equipment from ADVA, MRV, etc

Agenda

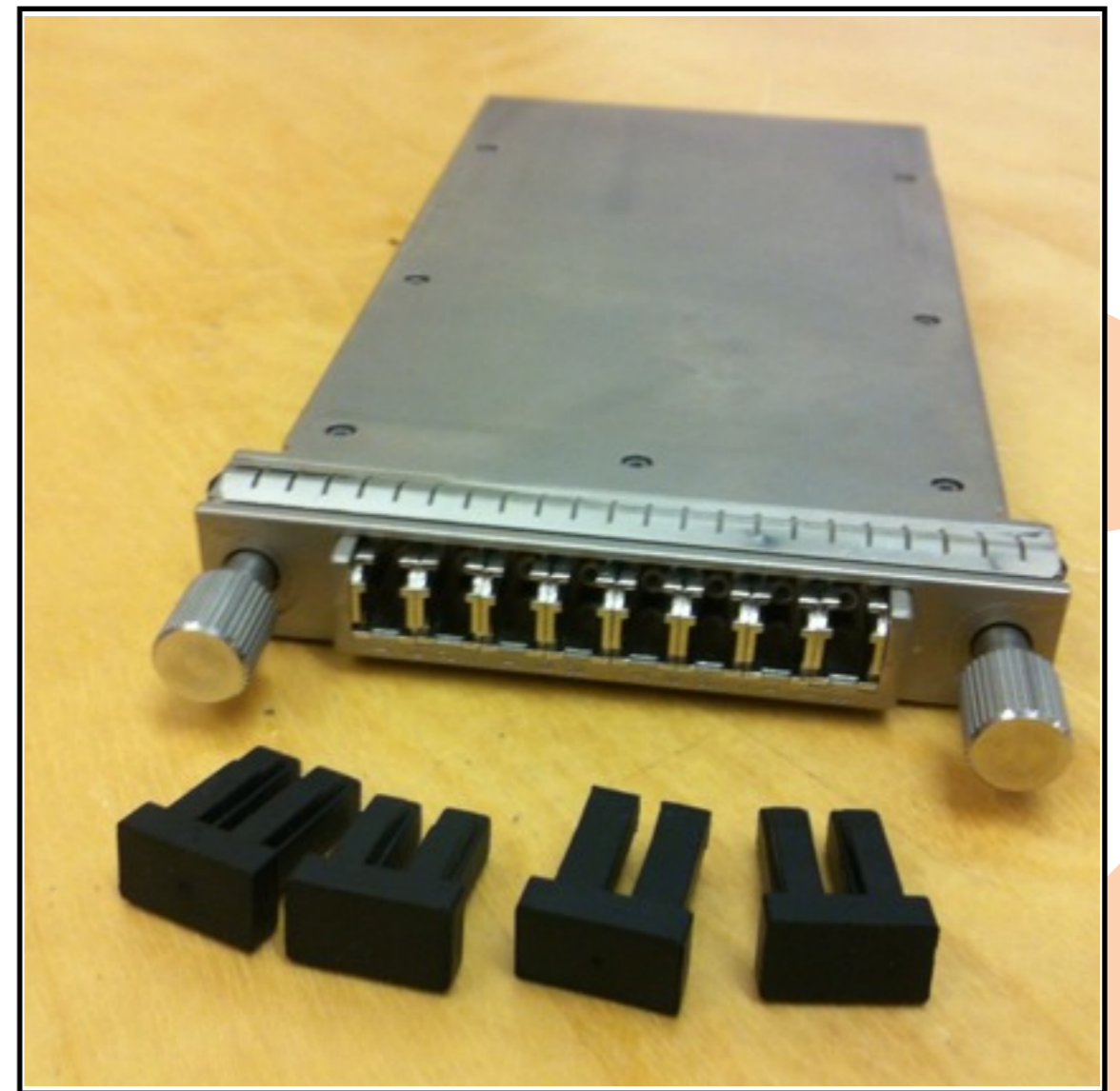
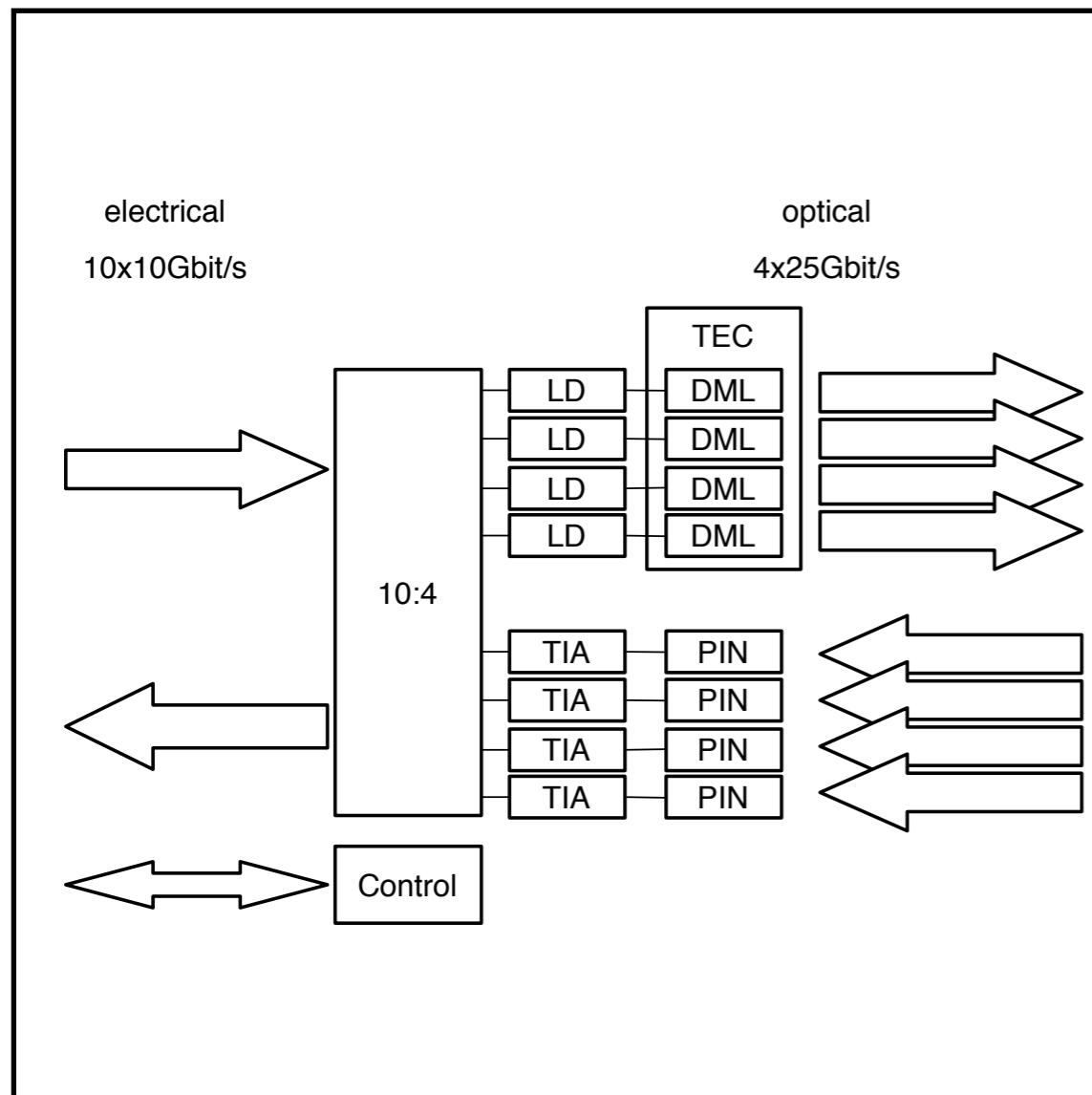
- AMS-IX
- 100Gbit/s technology
- Problem statement
- Optical Amplification
- **Metro DWDM equipment**
- Production results



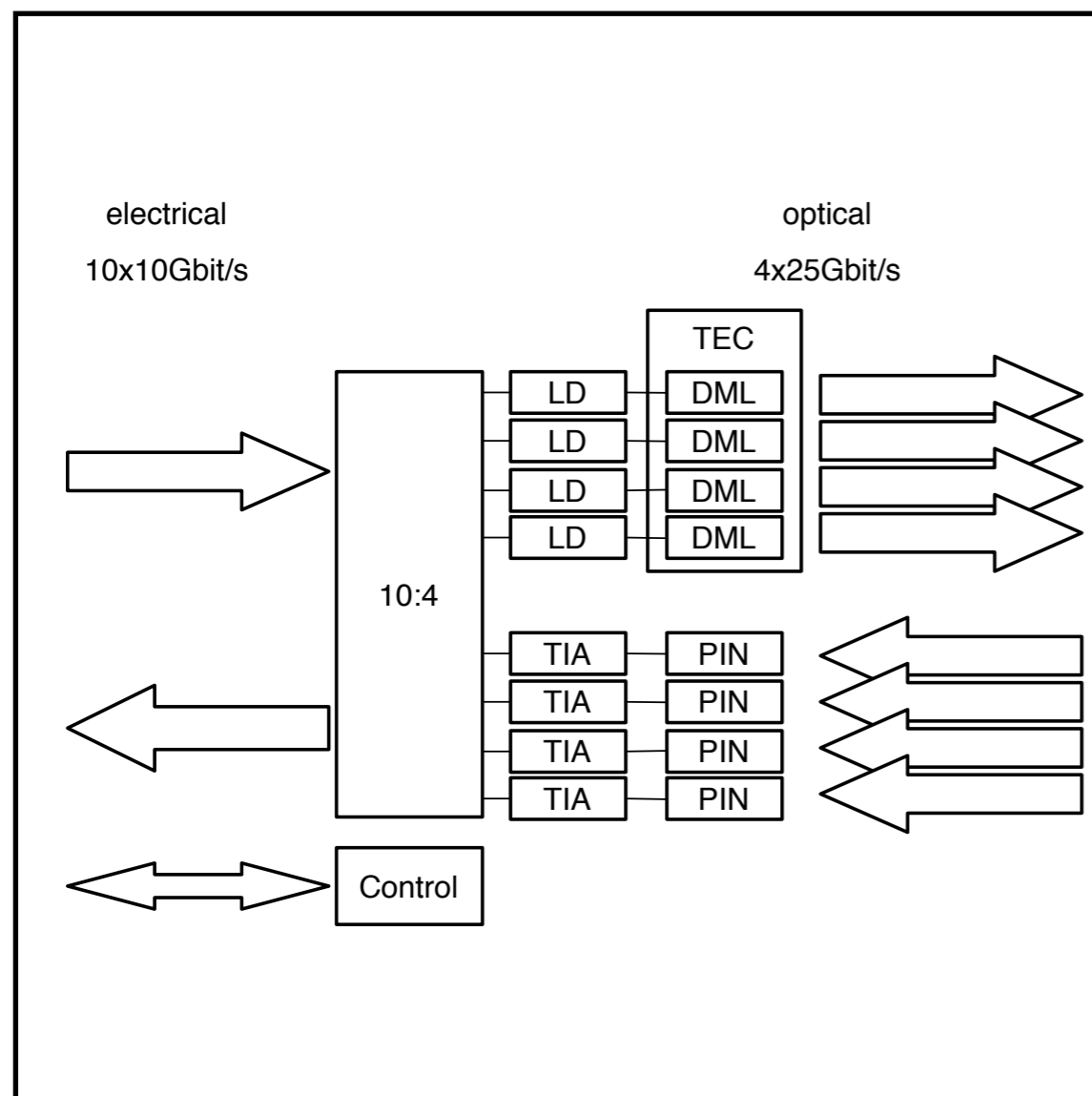
Metro DWDM



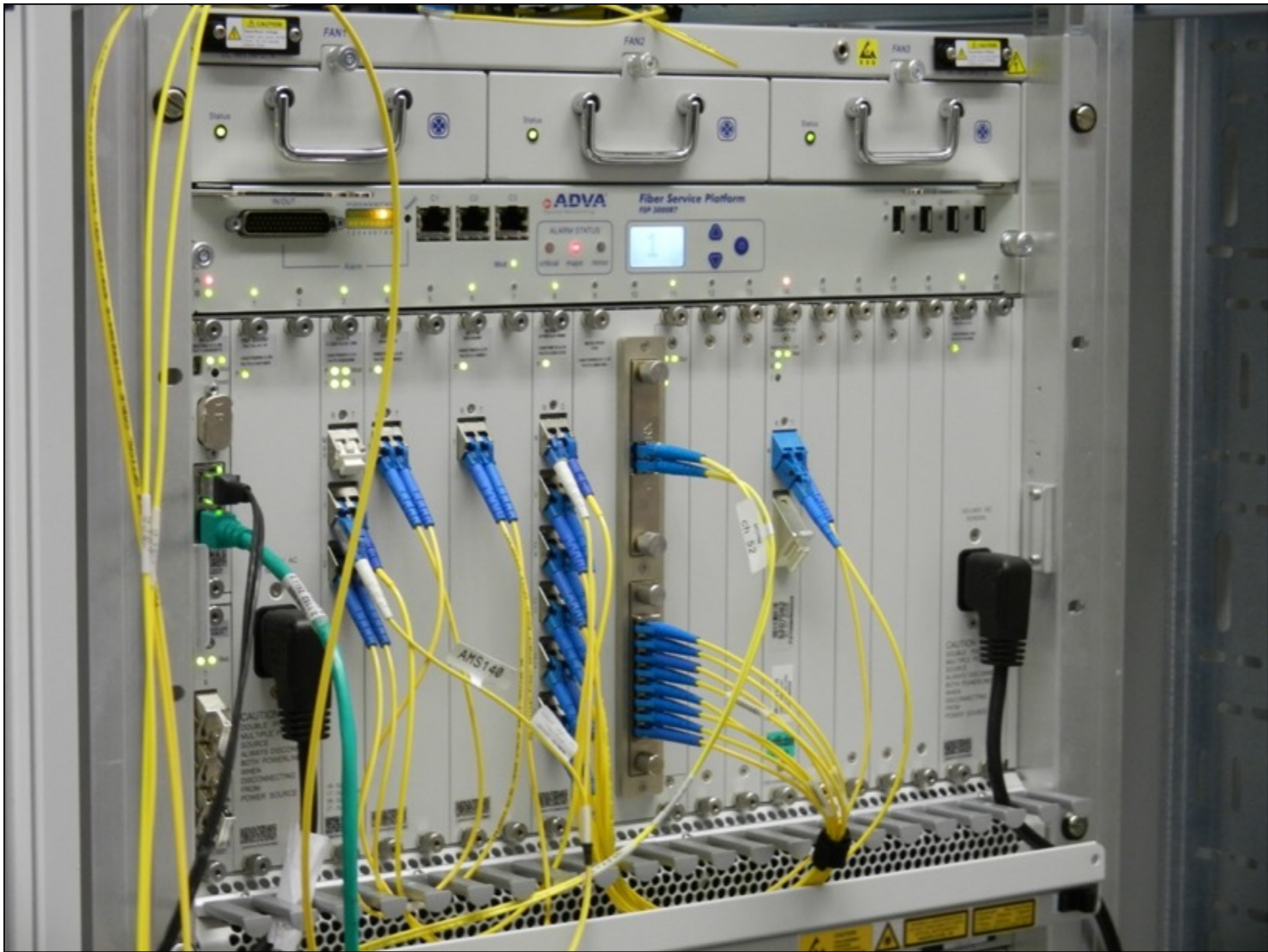
Metro DWDM



Metro DWDM



- We also installed ADVA equipment
- Finisar CFP without built in muxes
- 1550nm 4 x 28Gbit/s on 50GHz ITU grid
- Allows for FEC
- Successful over 45km where SOA could not make it error free.



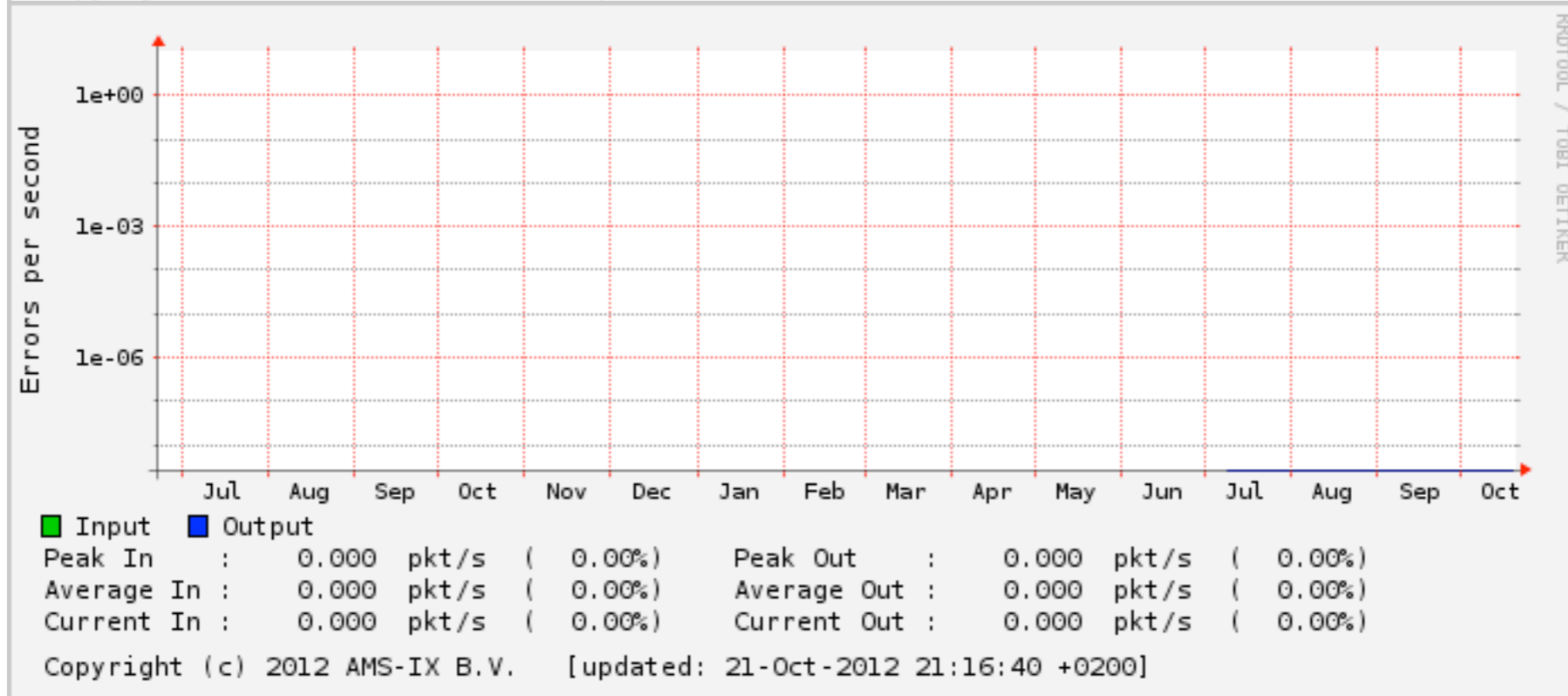
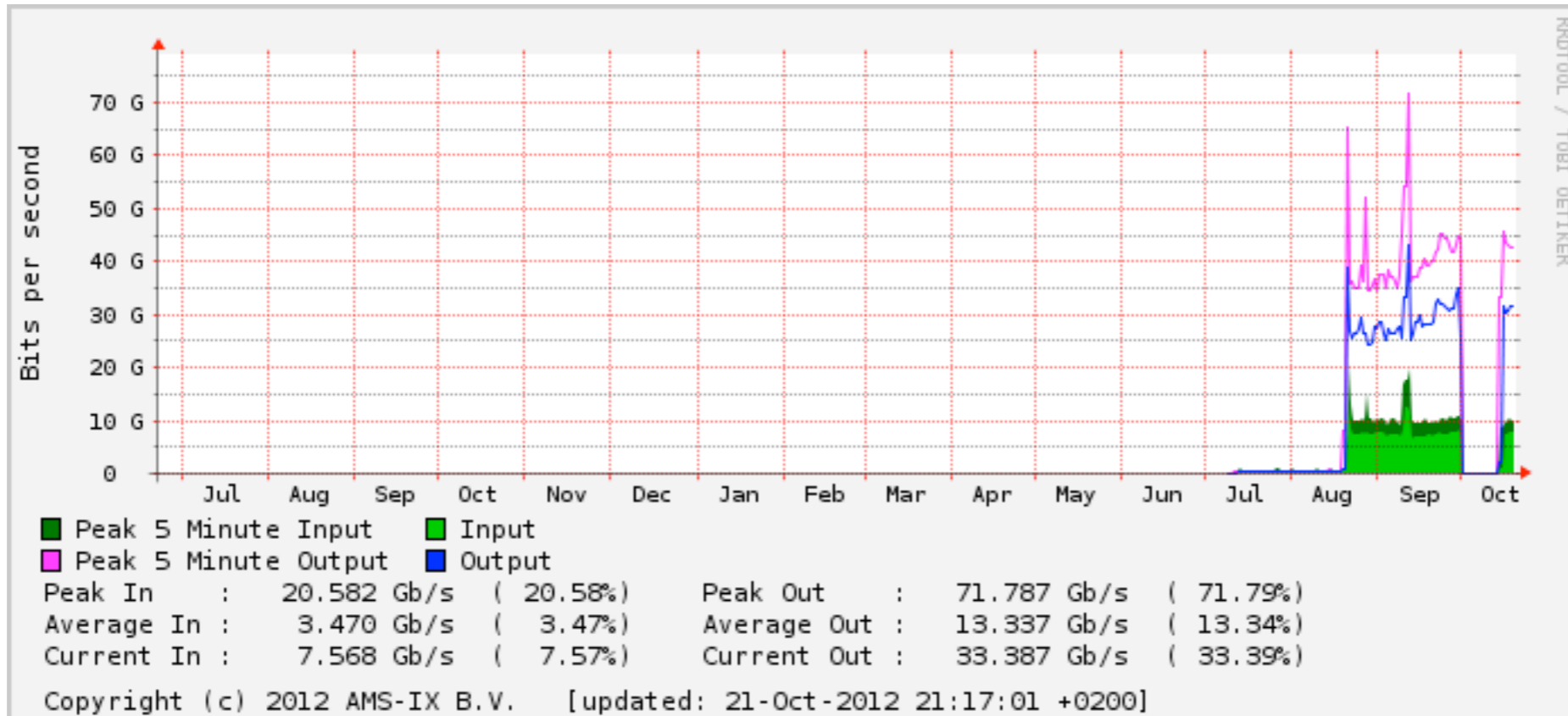
Agenda

- AMS-IX
- 100Gbit/s technology
- Problem statement
- Optical Amplification
- Metro DWDM equipment
- **Production results**

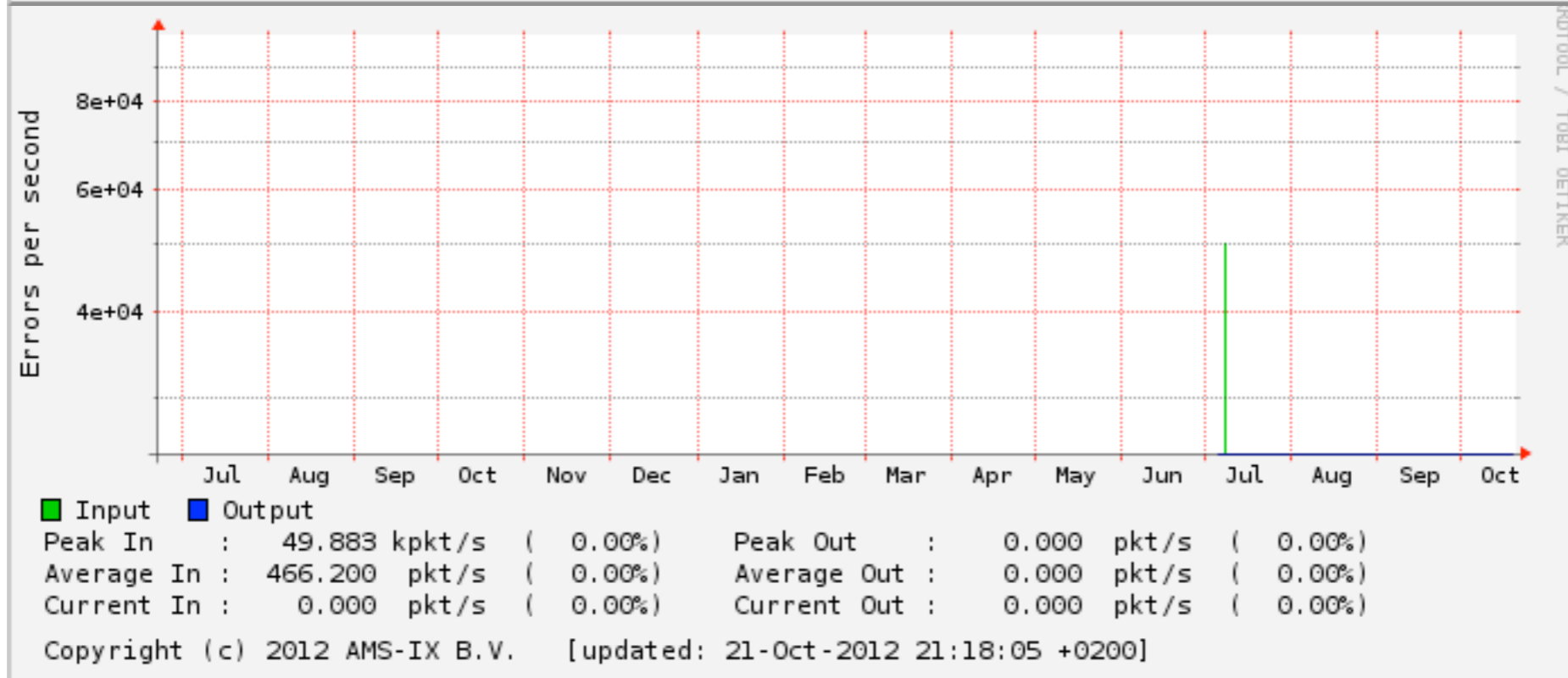
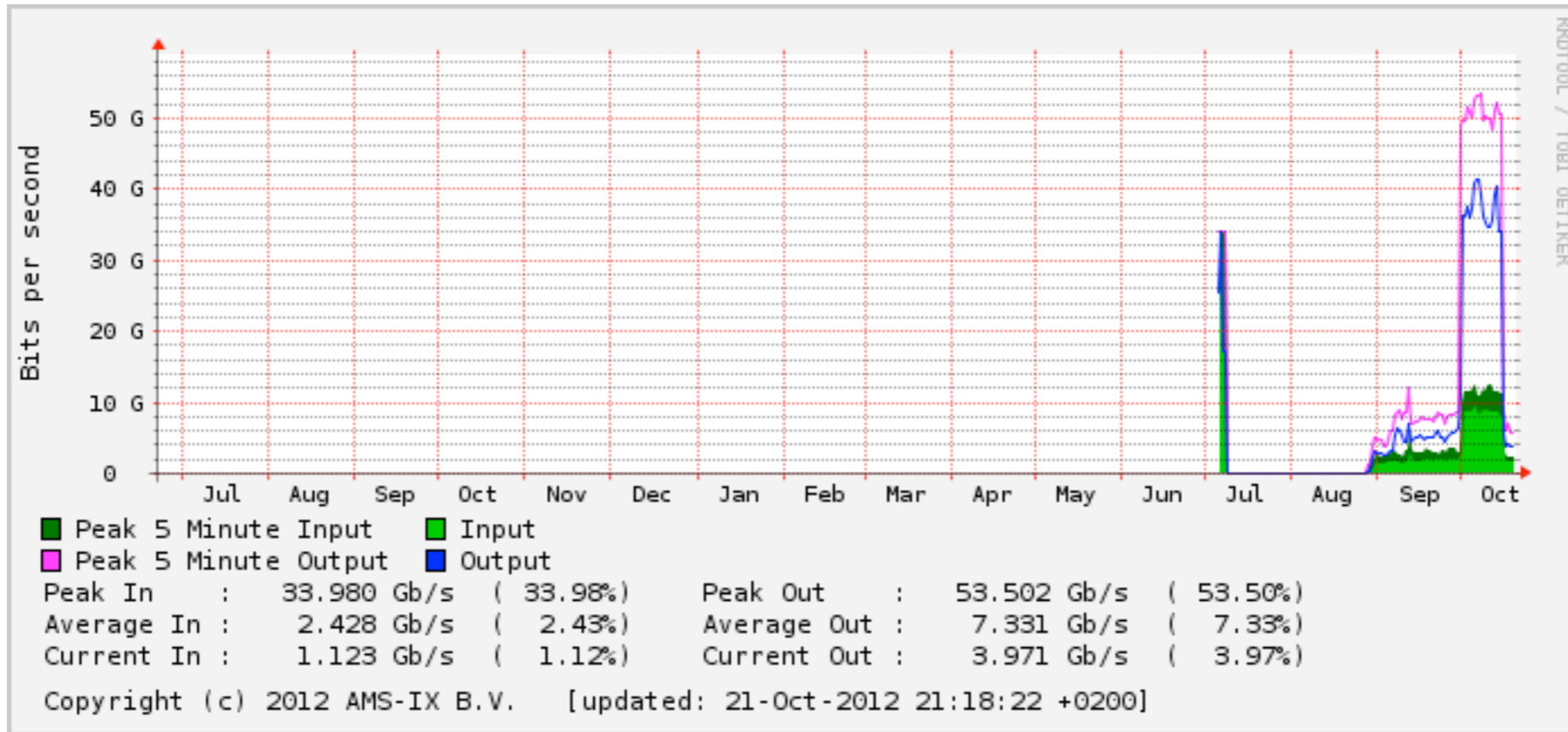




Link #1 GlobalSwitch <-> EvoSwitch (22km, PDFA)



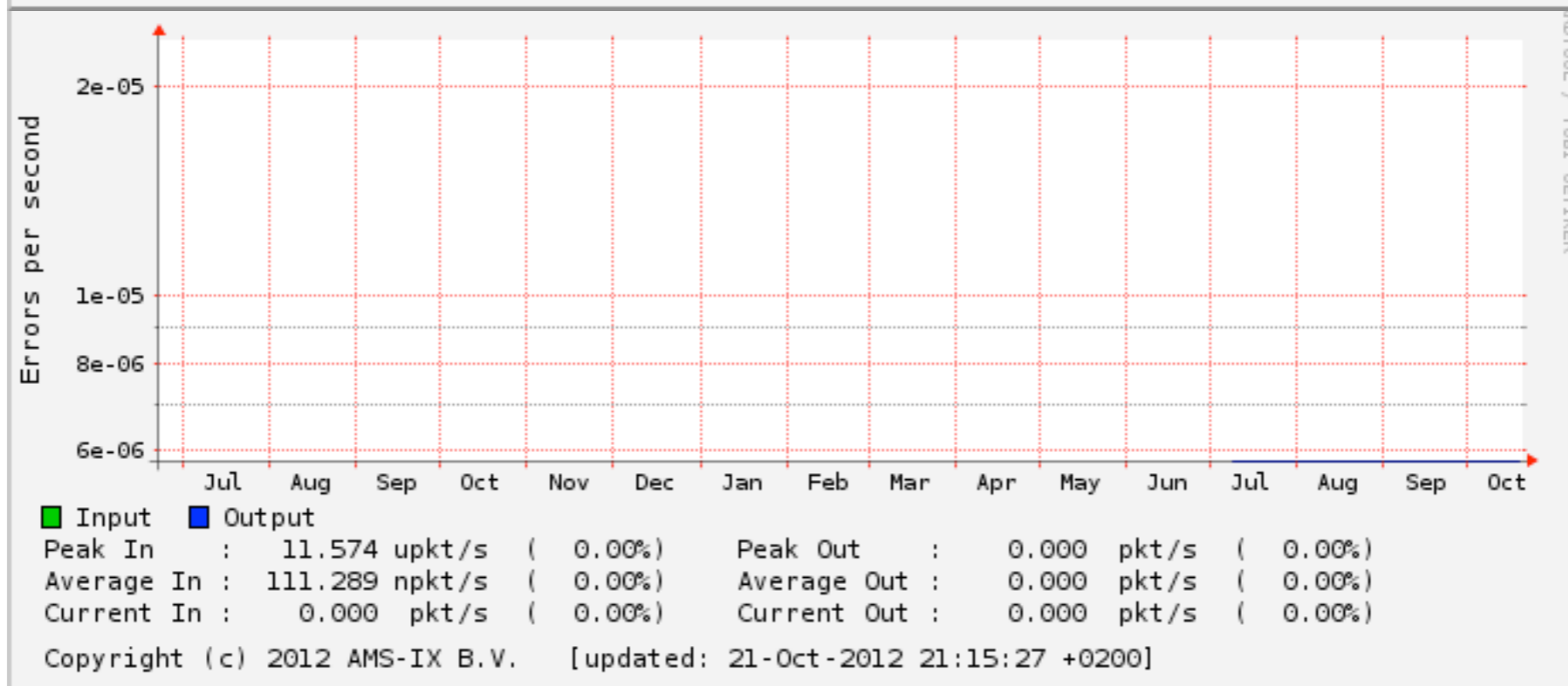
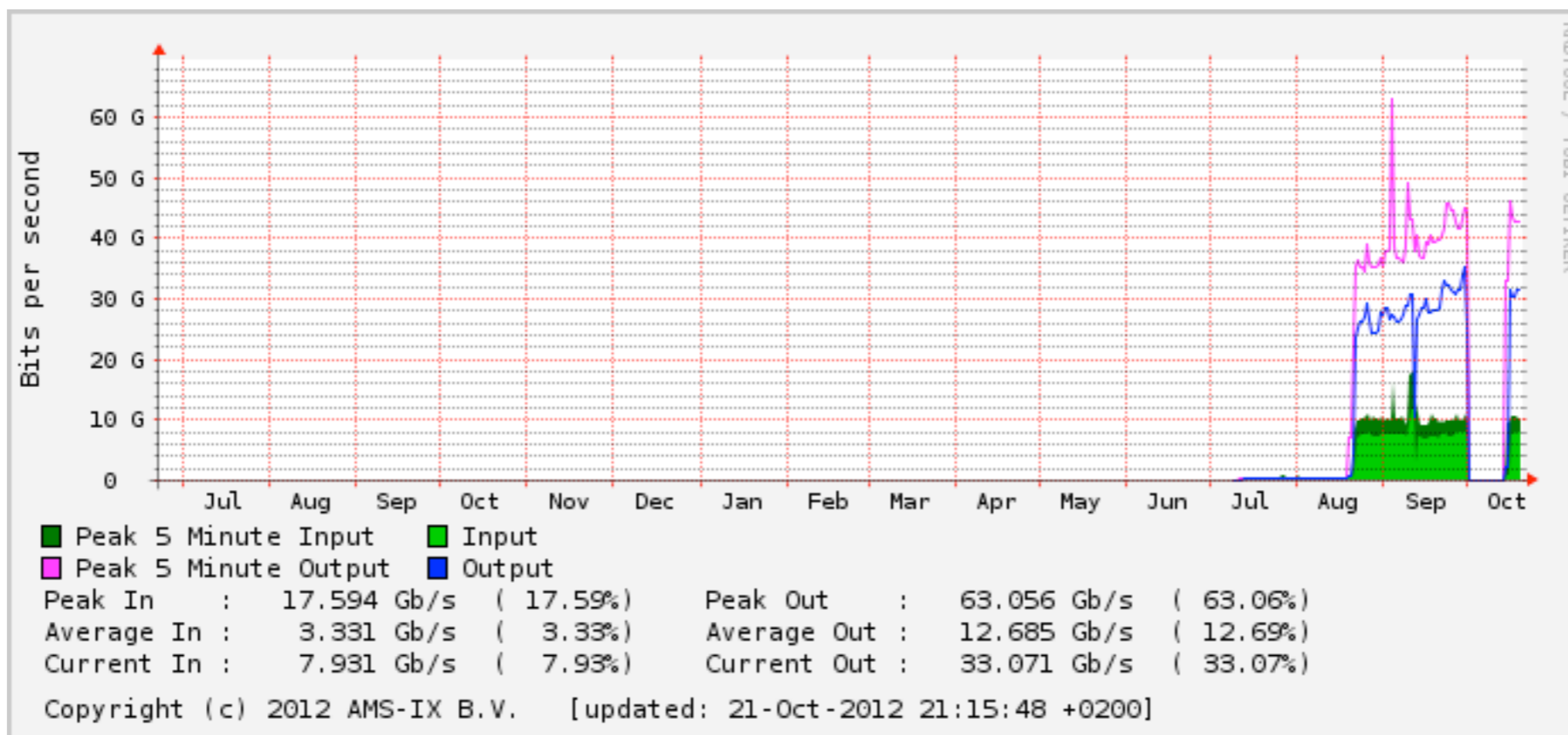
Link #2 GlobalSwitch <-> EvoSwitch (22km, SOA)



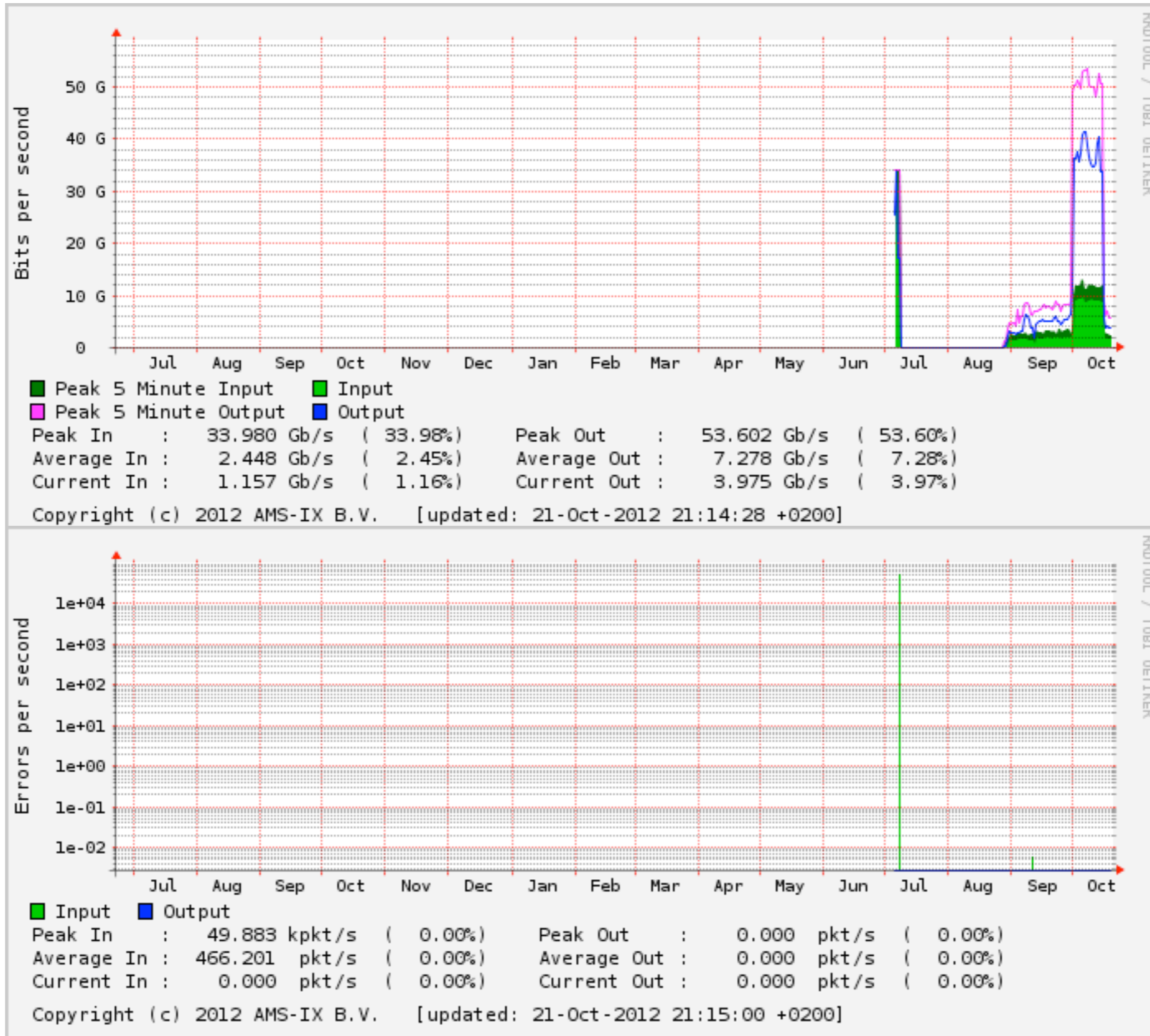
RRDTOOL / TOBI OETIKER

RRDTOOL / TOBI OETIKER

Link #1 euNetworks <-> EvoSwitch (32km, SOA)



Link #2 euNetworks <-> EvoSwitch (32km, SOA)



Production results

- SOA
 - 32km and 22km.
 - Errors while tuning in.
 - Not plug and play technology.
 - No to a few errors while in production.



End

Comments & Questions

