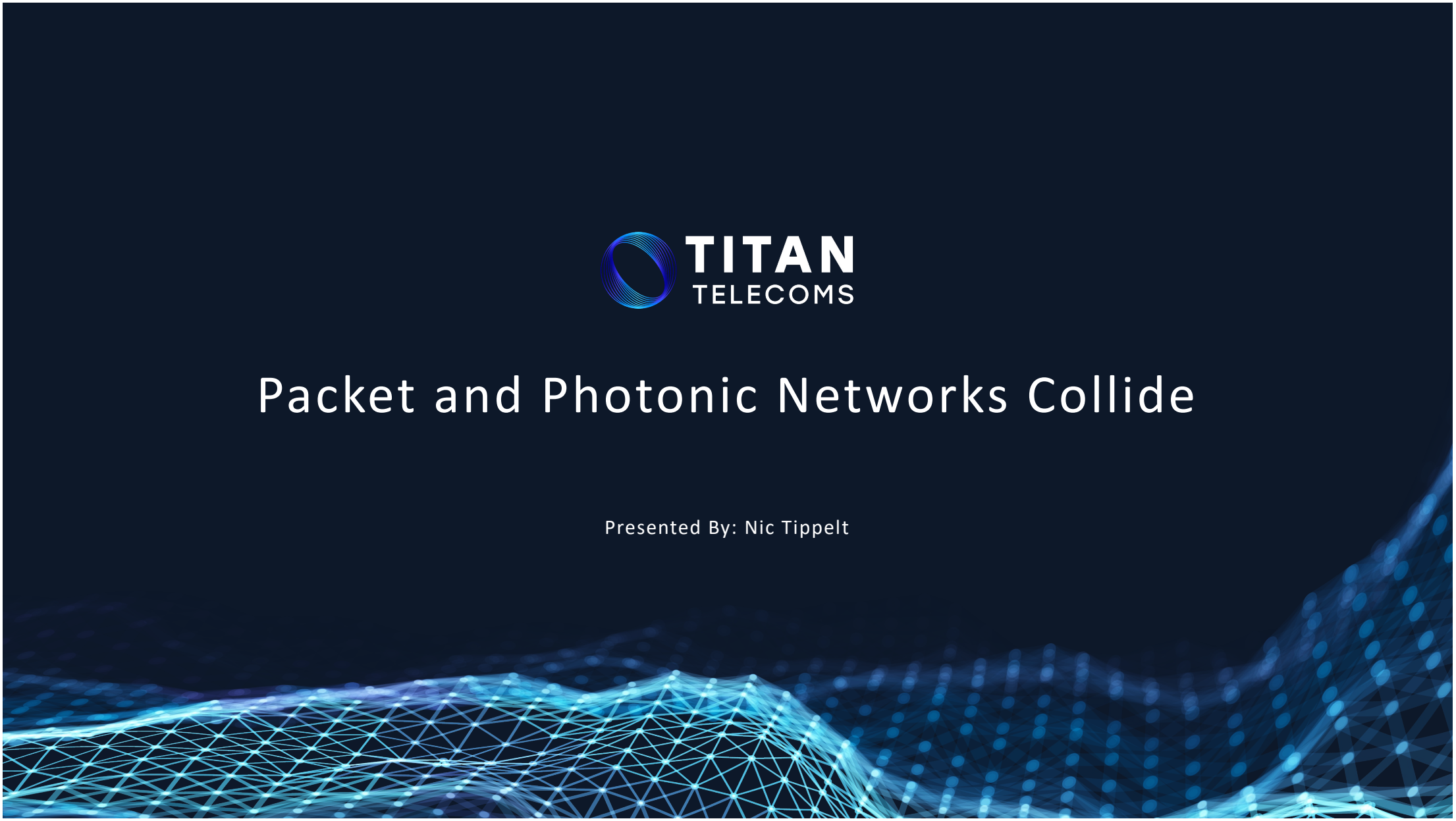
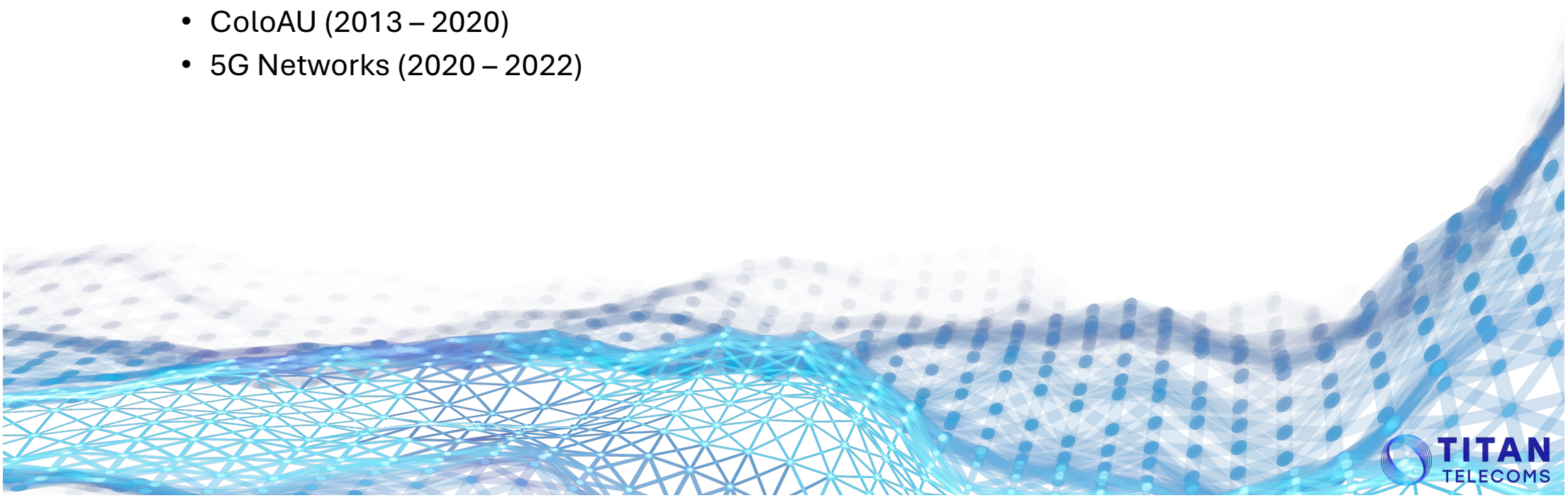


Packet and Photonic Networks Collide

Presented By: Nic Tippelt

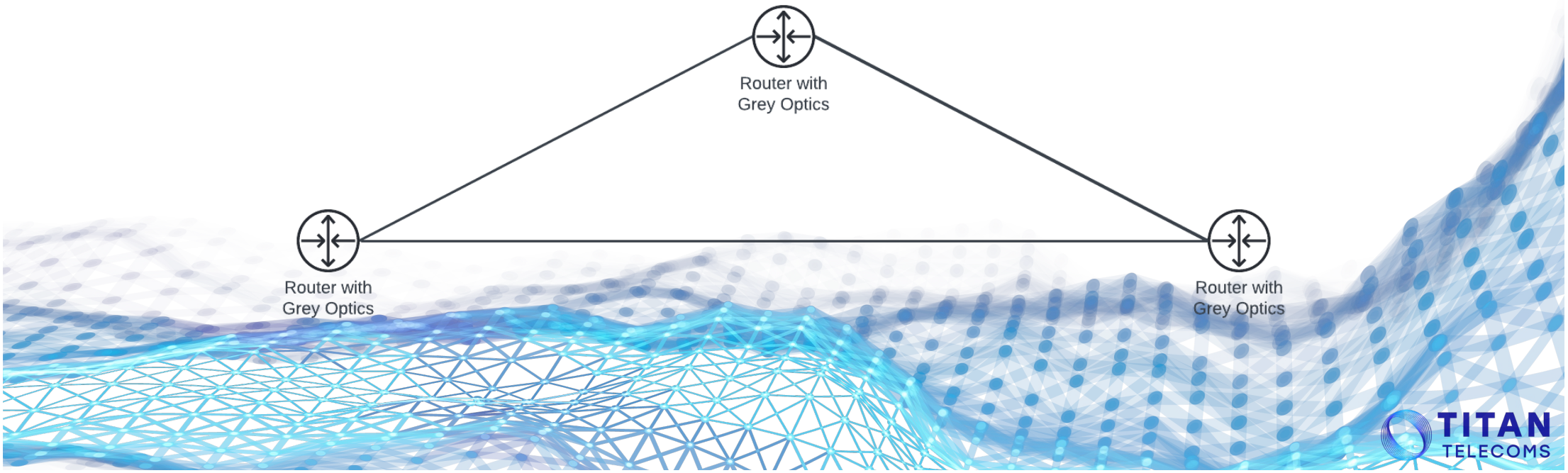
Who am I?

- Involved with Data Centre / Telecom Businesses for ~12 years
- Currently at Titan Telecoms (2022 – now)
- Previously;
  - ColoAU (2013 – 2020)
  - 5G Networks (2020 – 2022)



So lets talk building networks

- We have our routers directly connected with “grey” optics via dark fibre
- Typically 10G-LR or 100G-LR4



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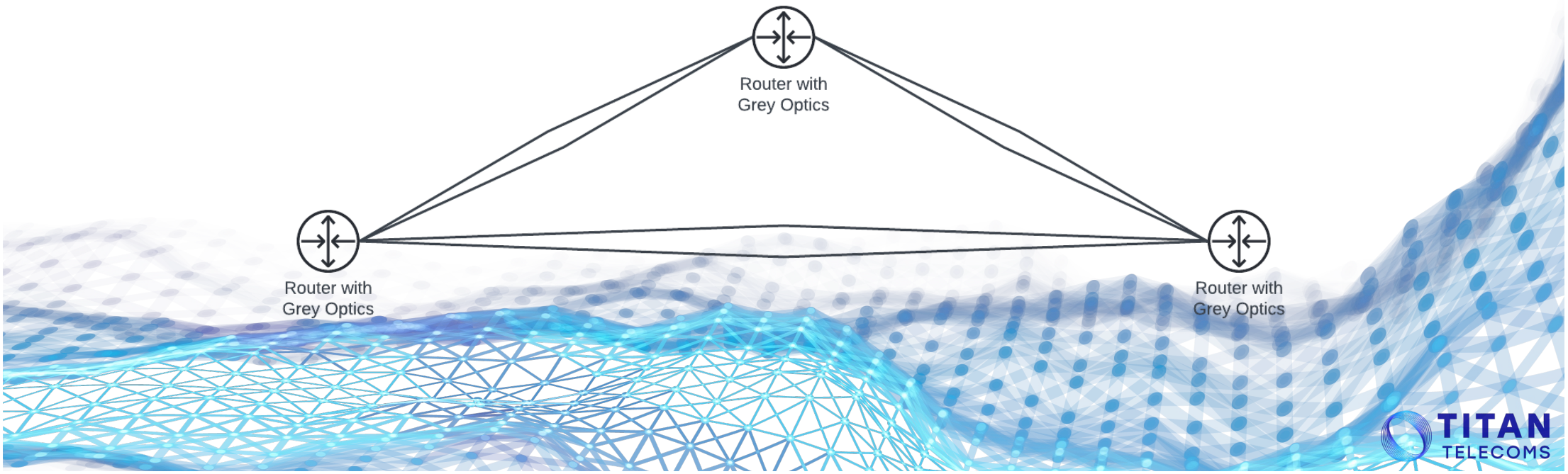
So lets talk building networks

- As capacity requirements grow – so do site interlinks leading to excessive volumes of fibre, multiple paths, cross connects.
- Largely static, upgrades require additional fibre



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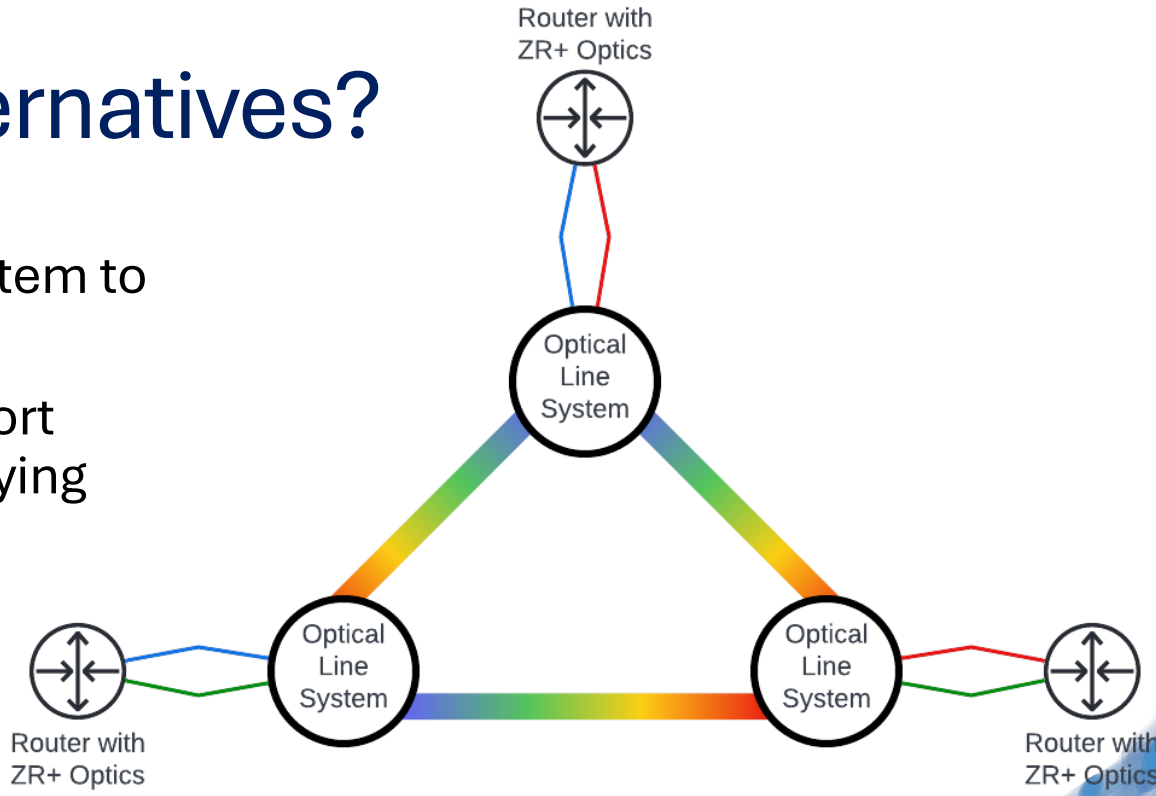
So what are the alternatives?

- Introduction of Optical Line System to provide WDM support
- Coherent pluggable allow support for direct connectivity to underlying Optical Transport Network



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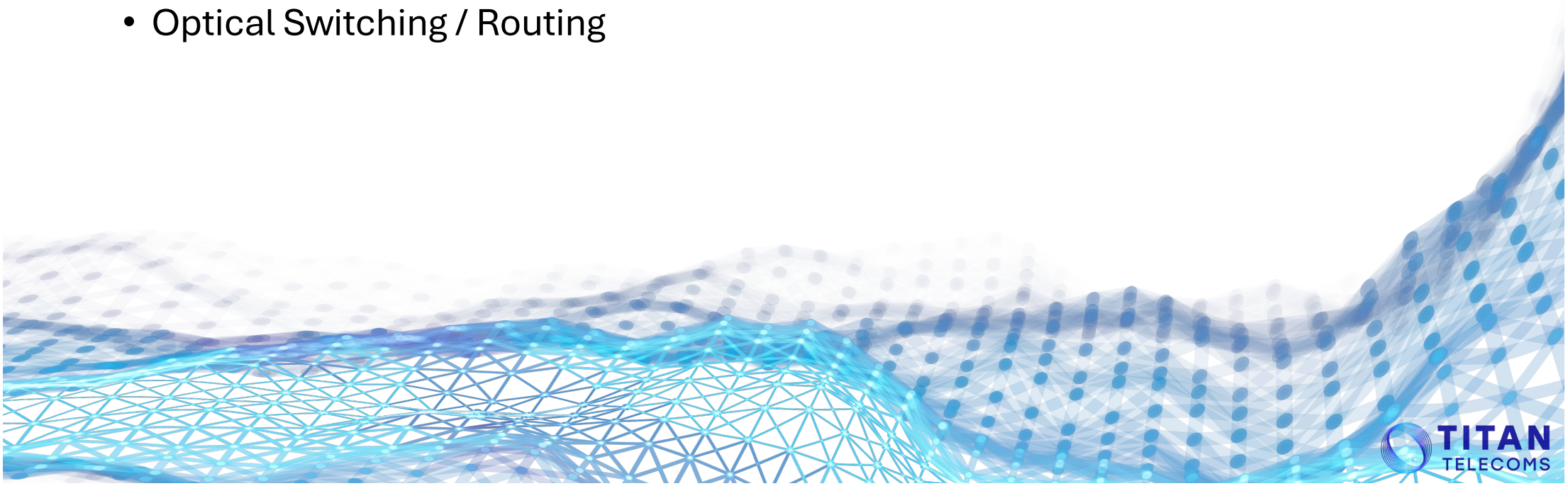
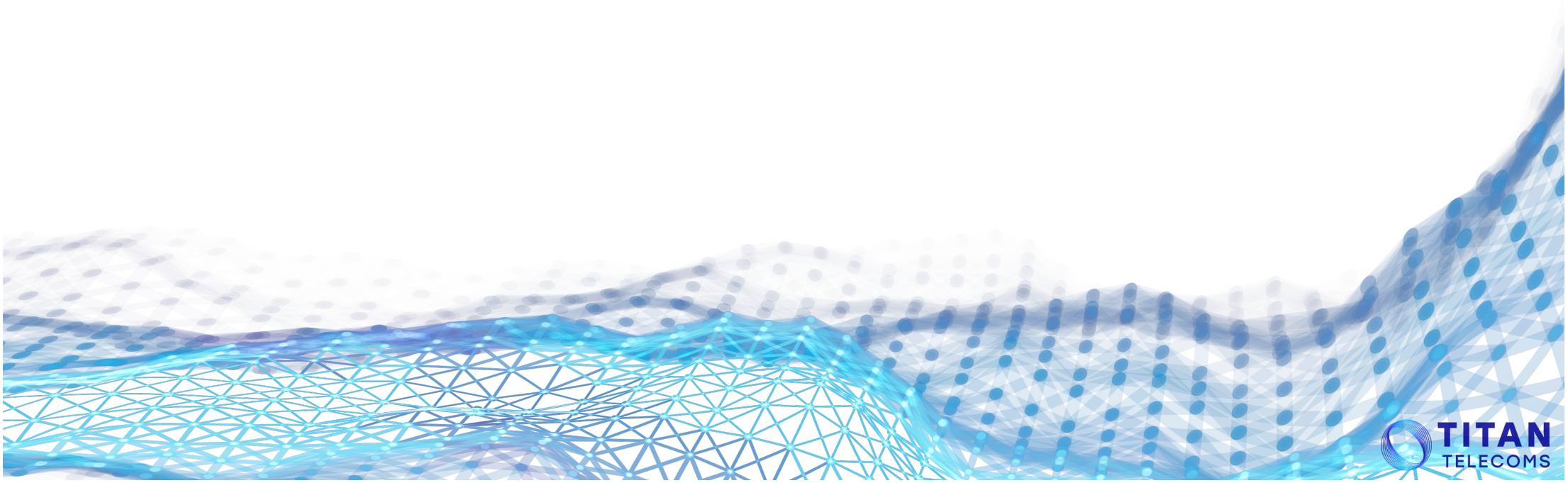
So what is an Photonic / Optical Line System?

- Optical Fibre Transmission
- Light-Based Signal Processing
- Wavelength Division Multiplexing (WDM)
- Optical Switching / Routing



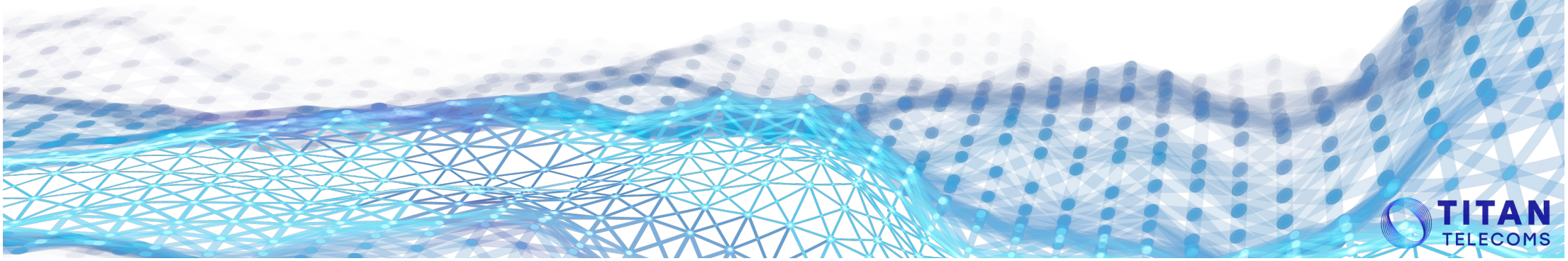
Optical Line System Use Cases

- Terrestrial and Submarine Long Haul
  - OLS & WDM using amplification techniques allow compensation of attenuation over extreme fibre distances
- Bandwidth Maximisation on low fibre core count routes.



Optical Line System Growing Need

- As networks scale to meet the unprecedented growth of backbone capacity due to a variety of factors, such as;
  - Artificial Intelligence
  - Streaming
  - Creative Industries
  - Scaling Last Mile Connectivity
- Photonic Networks with modern pluggables provide solution by allowing a flexible, scaling backbone, with pluggable coherent transceivers in backbone devices



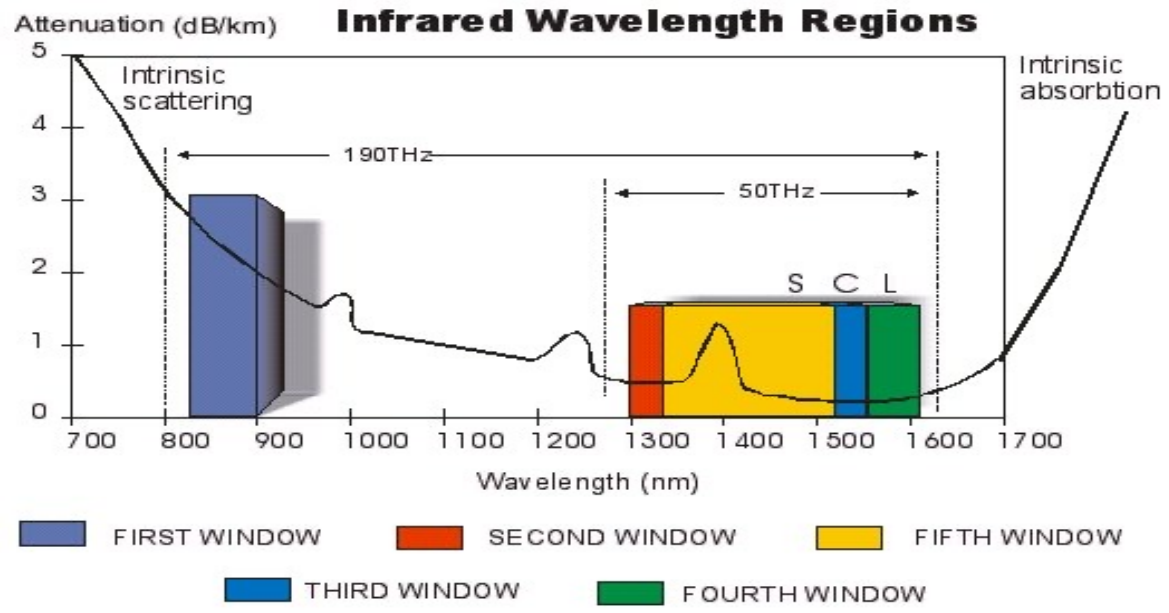
Basics of Optical Line Systems

Photonic Networks Building Blocks

- Wavelength Division Multiplexing (WDM)
  - Multiplexer / Demultiplexer
- Optical Amplification
  - Erbium Doped Fibre Amplifier (EDFA)
  - RAMAN Amplifier
- Wavelength Selective Switch (WSS)
  - Reconfigurable Optical Add Drop Module (ROADM)
- Transponders

Transmission Bands

- Due to fibre characteristics, optical transmission can only be done in certain transmission bands



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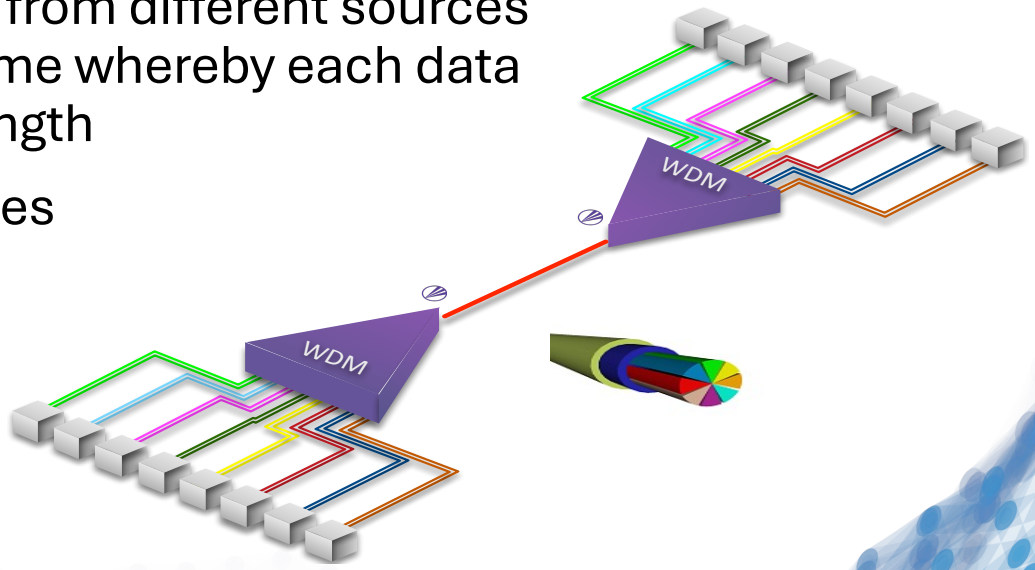
Wavelength Division Multiplexing (WDM)

- WDM is a method of transmitting data from different sources over the same fibre pair at the same time whereby each data channel is carried on a unique wavelength
- WDM can be used in multiple topologies
  - Point to Point
  - Ring
  - Linear Add/Drop
  - Star
  - Mesh



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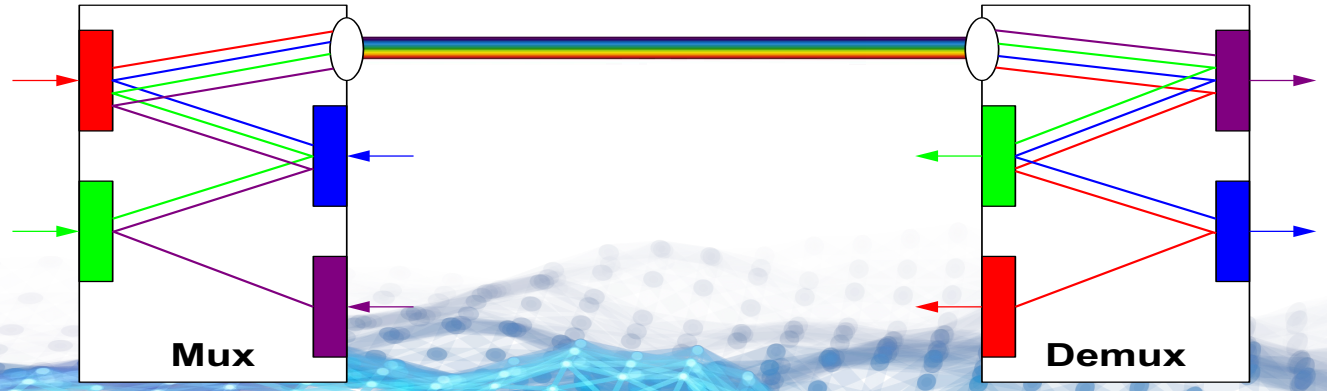
Multiplexer / Demultiplexer

- A Multiplexer (Mux) is a passive, optical device that combines channels of different wavelengths such that they all pass through a single optical fibre.
- A Demultiplexer (Demux) is a passive, optical device that separates combined (multiplexed) channels of different wavelengths such that they each emerge through a different fibre.



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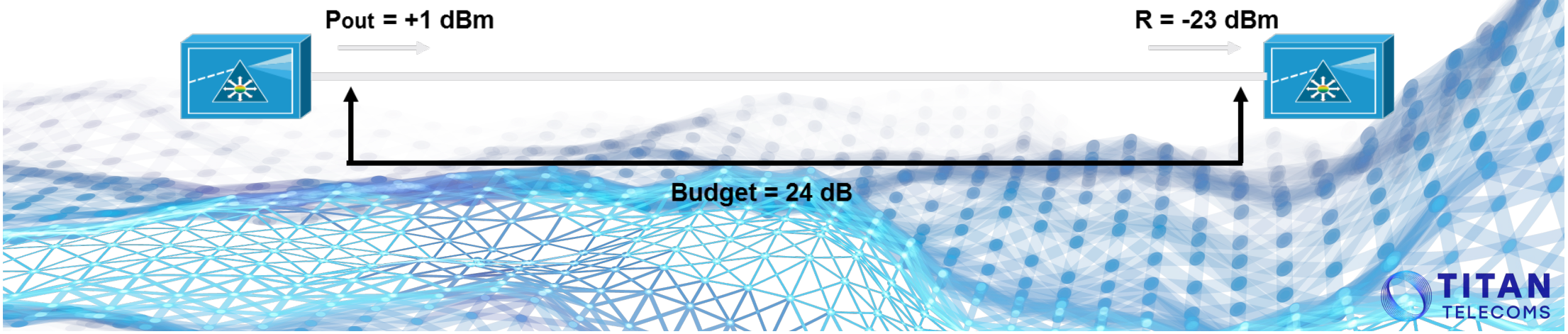
Attenuation

- Attenuation
  - Loss of signal along the distance
  - Affecting all signals over the fiber
  - Dependent on fibre type and wavelength

- Optical Budget is affected by:
  - Fiber attenuation
  - Splices, fusion or mechanical
  - Patch Panels & Connectors
  - Optical components (filters, amplifiers, etc)
  - Contamination



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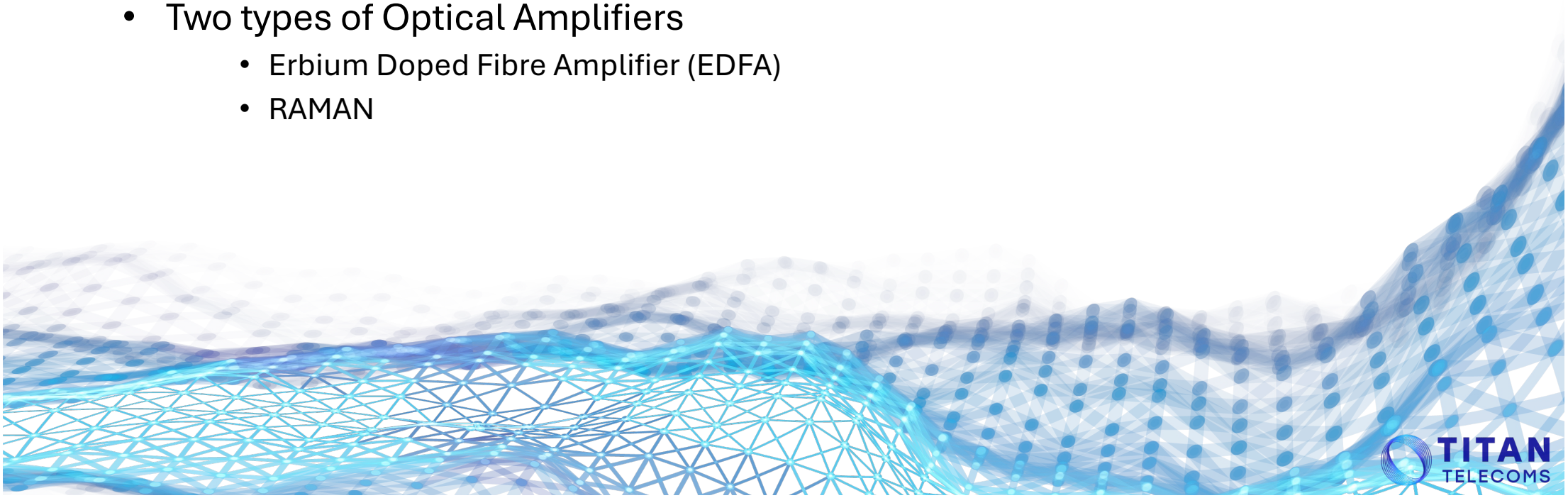
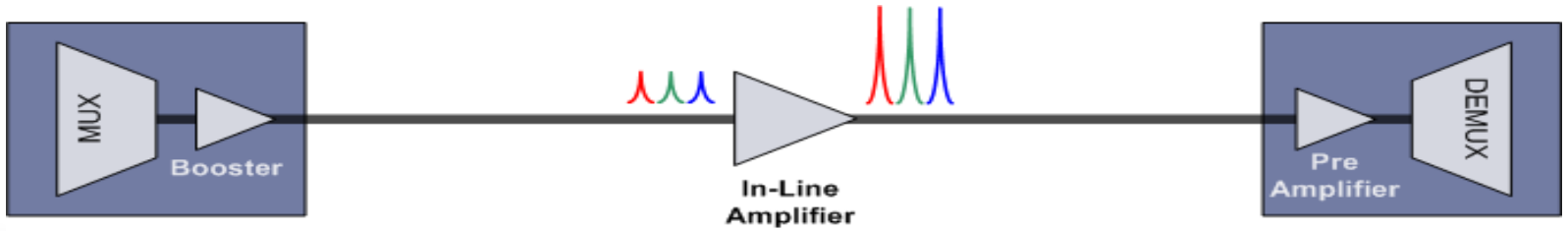
Optical Amplifiers

- Optical Amplifiers are used to compensate the attenuation of the fibre on longer distances
- Only DWDM band (C / L) can be amplified
- Two types of Optical Amplifiers
    - Erbium Doped Fibre Amplifier (EDFA)
    - RAMAN



Optical Amplifiers

- Amplifiers can be placed at
  - Begin of the fibre path (Booster)
  - Between begin and end point (In Line Amplifier)
  - At the end of the Fibre (Pre Amplifier)



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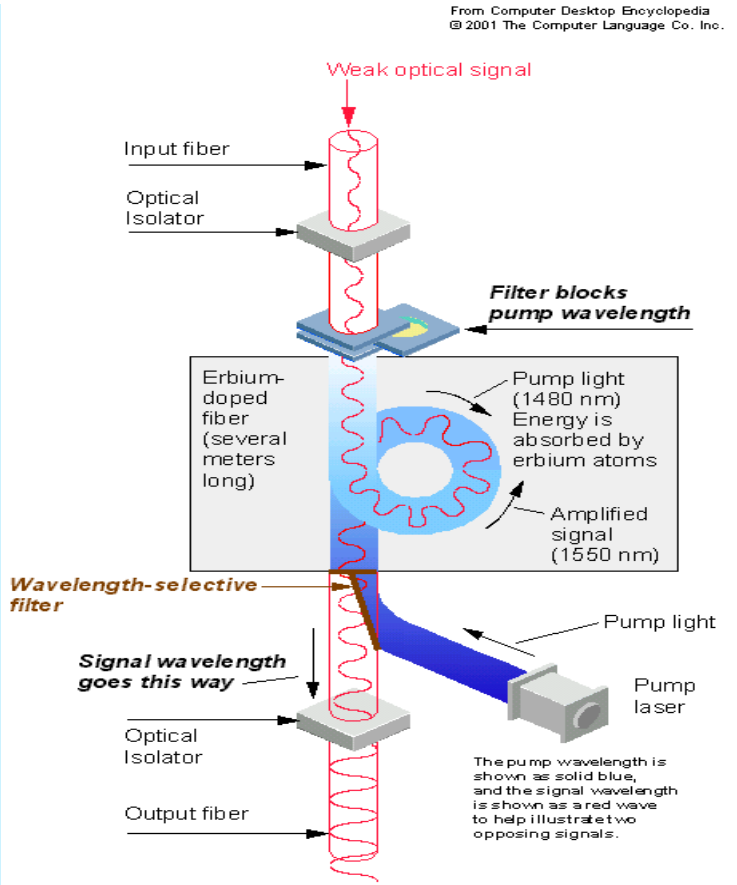
Erbium Doped Fibre Amplifier

- EDFAs are very common due to easy use, low power consumption, small size and relatively low cost,
- EDFA amplifiers uses a fibre, doped with the element Erbium
- Photons of the pump laser will resonate in the DWDM band
- EDFA amplifier adds additional noise to the signal



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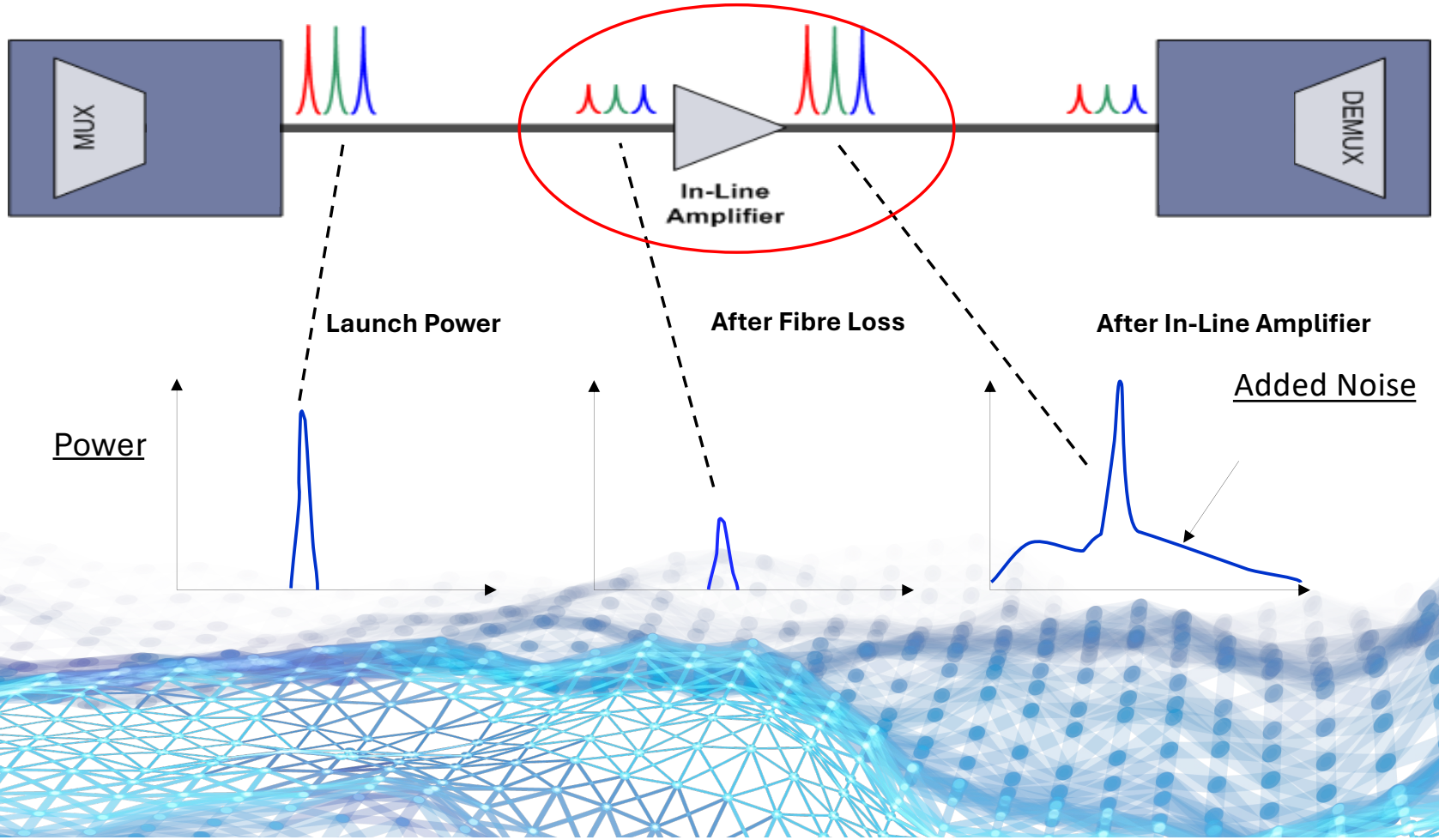
Erbium Doped Fibre Amplifier Example



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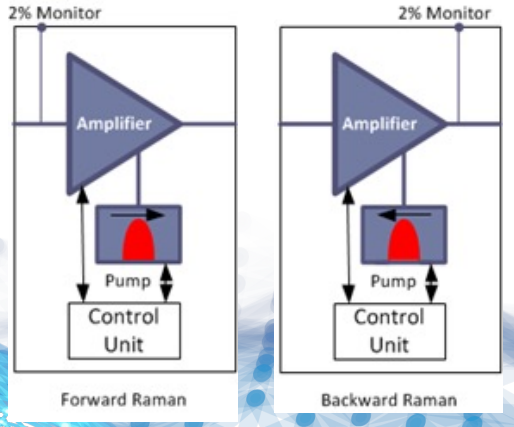
RAMAN Amplifiers

- When dealing with long spans and high data rate signals, RAMAN technology is preferred over EDFA
- Raman Amplifier uses the actual transmission fibre as the gain medium, providing distributed amplification
- Amplification is achieved by nonlinear Stimulated Raman Scattering (SRS) between the signal and a pump laser



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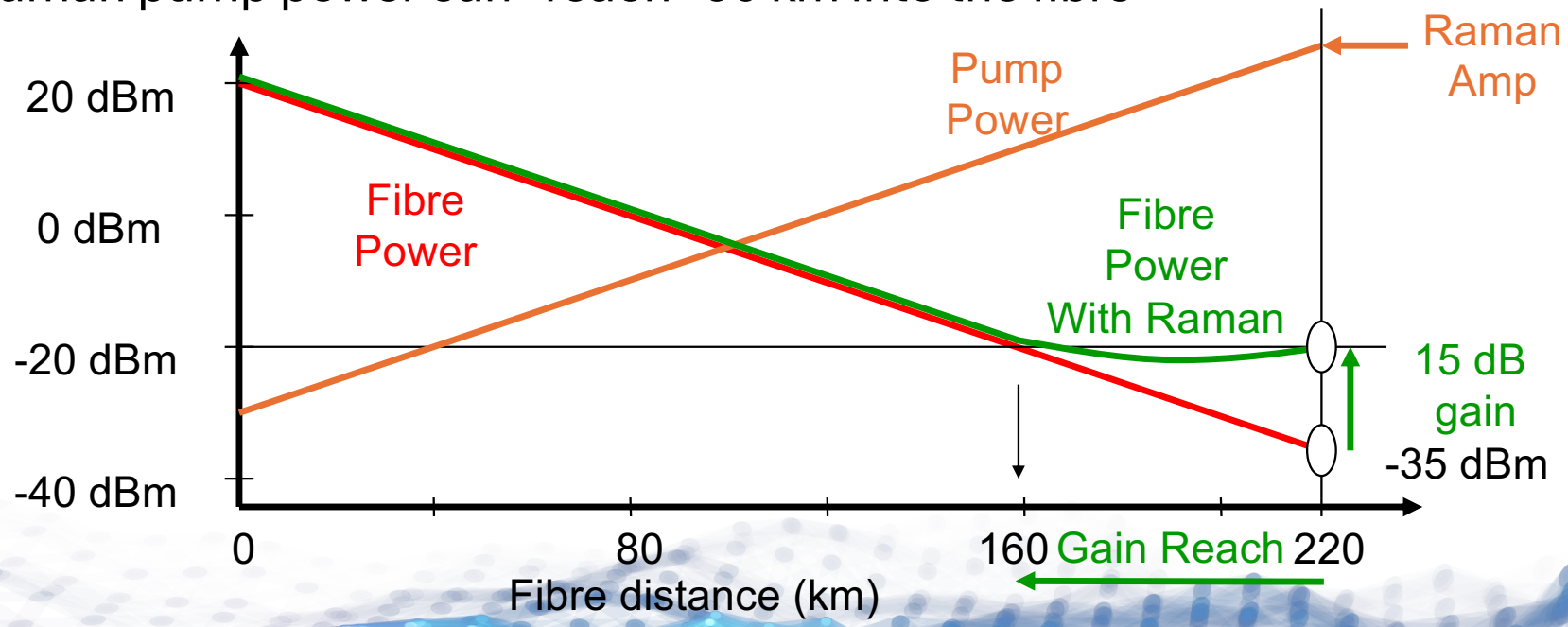
RAMAN Amplifier Example

- Raman pump power can “reach” 90 km into the fibre



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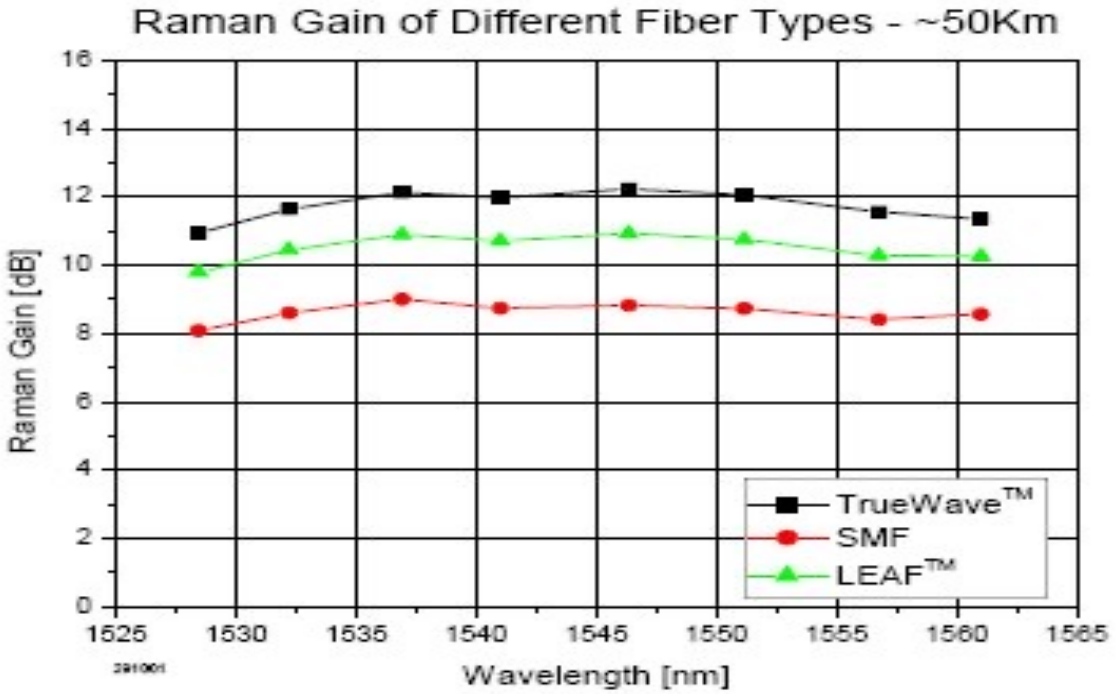
RAMAN Amplifiers

- Raman amplifiers consume 100 times more power per dB of Gain than EDFA
- Gain is flat over entire C-band
- Since Raman uses transmission Fibre as amplification medium, gain is dependent on Fibre type and cleanness



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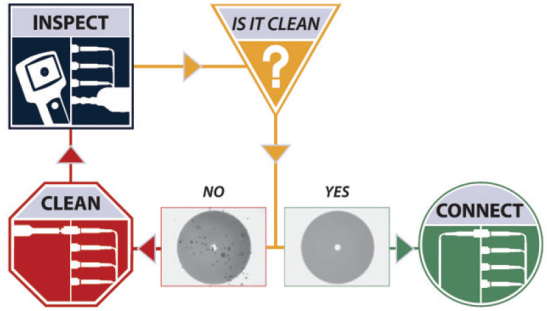
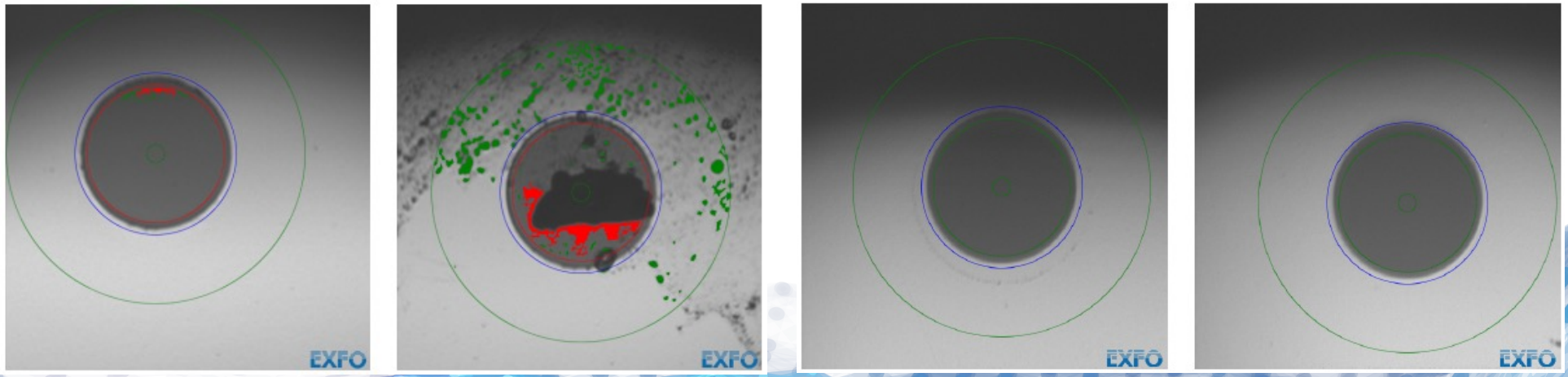
Slight Segway



- ALWAYS inspect the connector before connecting to the Raman
- Due to RAMAN Amplifications high power gain miss matched connectors (APC / UPC) or directly connectors can have disastrous outcomes..



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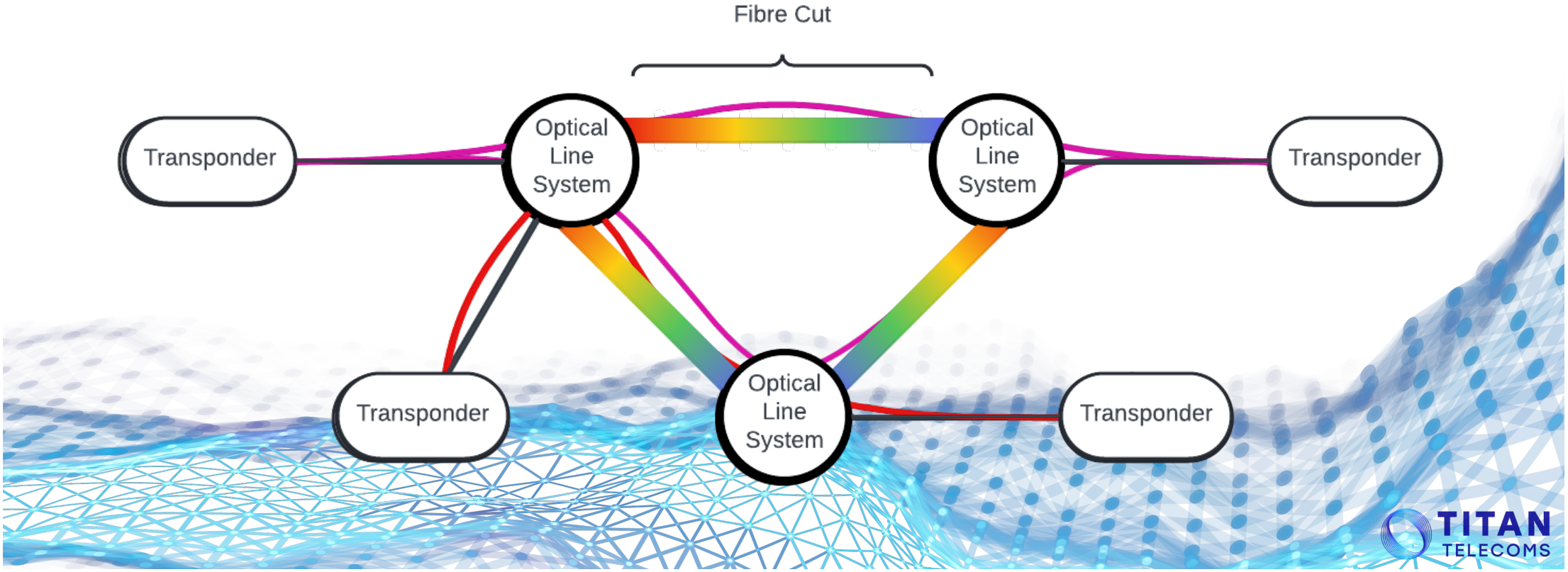
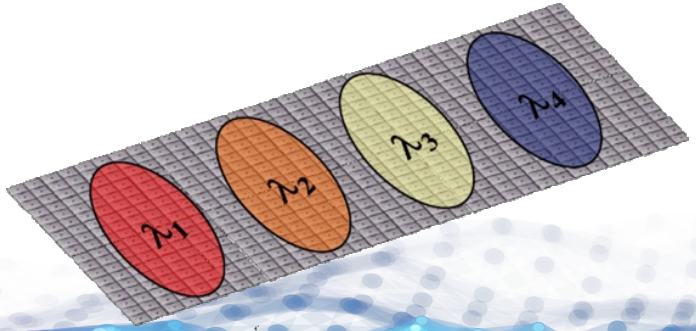
Reconfigurable Add Drop Module (ROADM)

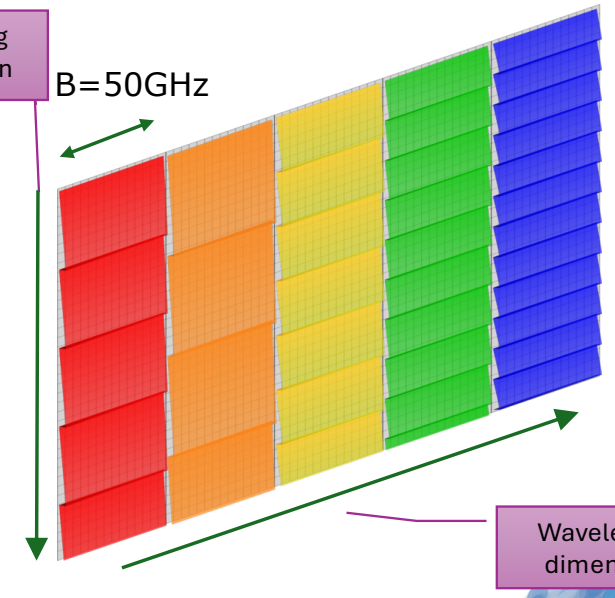
- Dynamic management of network, using add, drop and passthrough functionality leading to improved controls of underlying network.



ROADM Switching

- Liquid Crystal on Silicon technology (LCoS)
  - Technology used in some LCD projection televisions
  - Array of multiple liquid crystals applied on a silicon chip
  - Wavelengths are first dispersed across width of LCoS
  - Voltage level pattern adjusts LC molecule structure which has effect on attenuation and phase retardance of the wavelength





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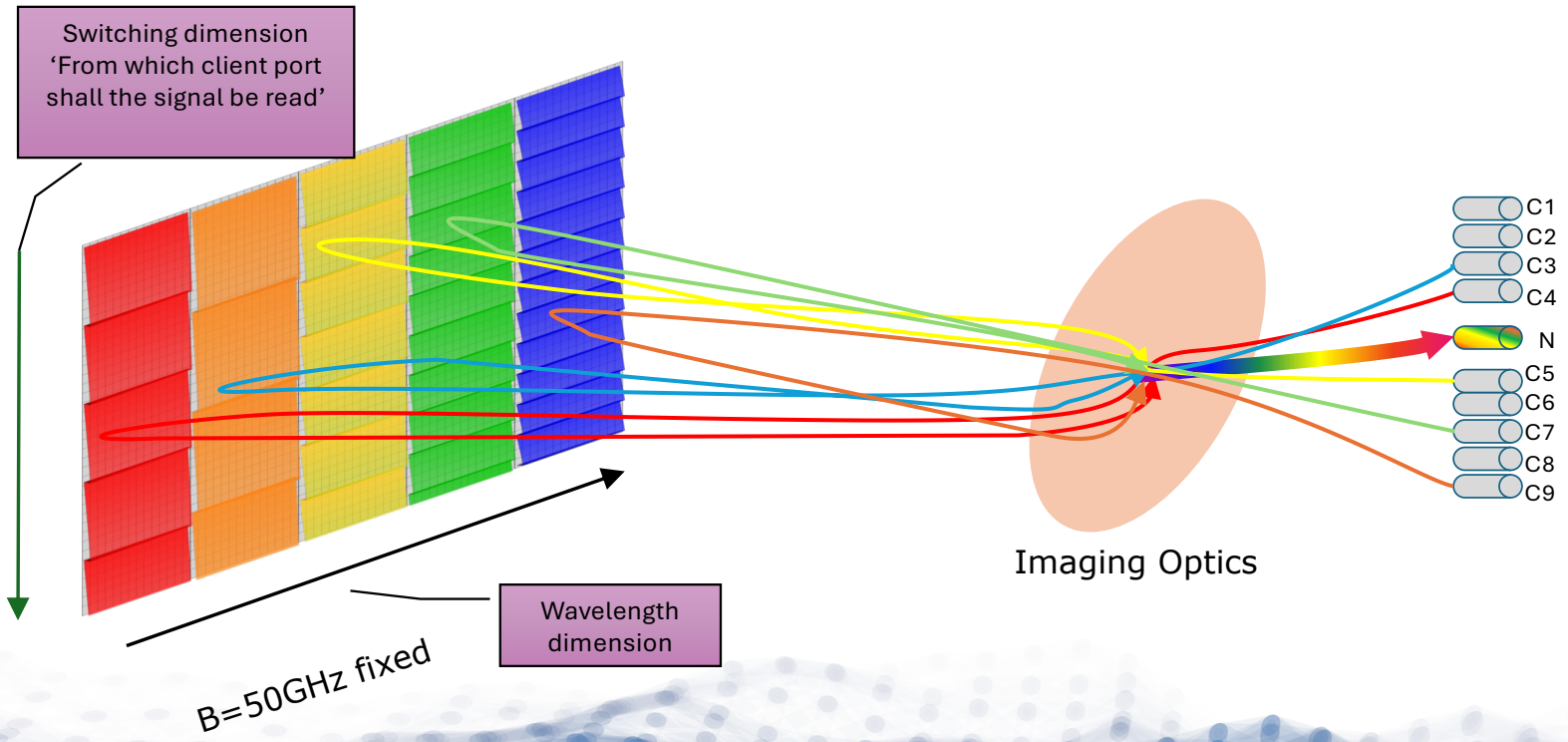
ROADM Switching



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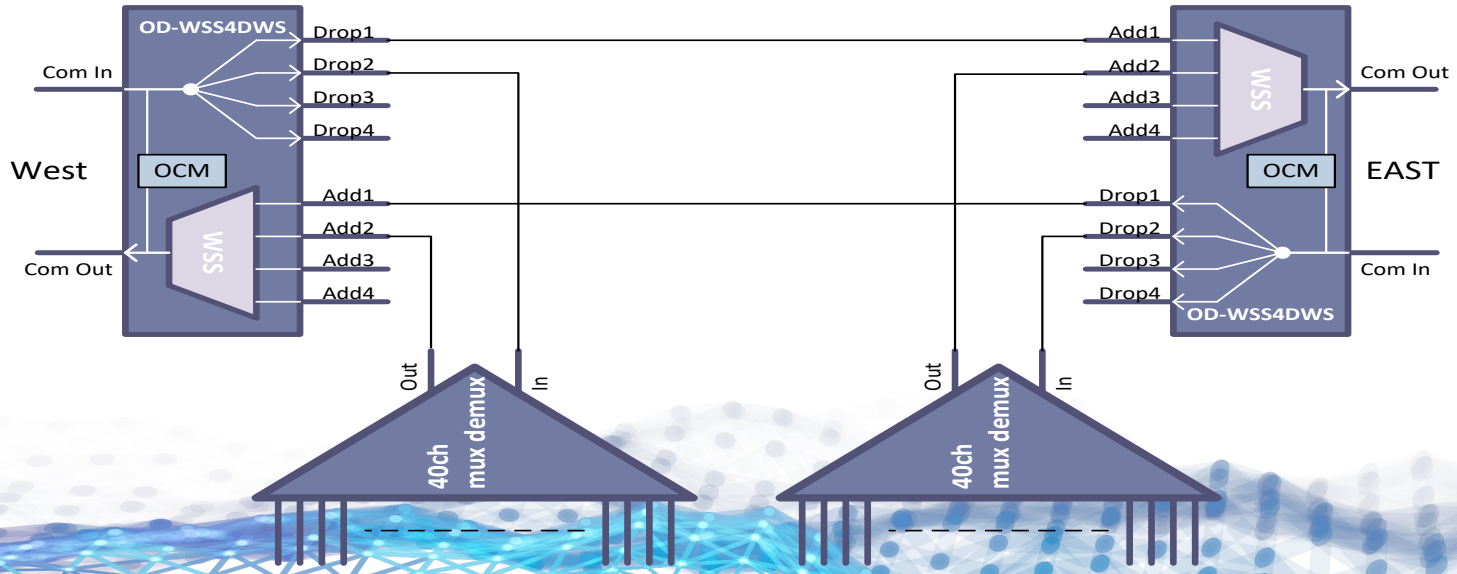
ROADM Example

- Example of a two degree ROADM node allowing for EAST / WEST passthrough & break out via a fixed filter multiplexer



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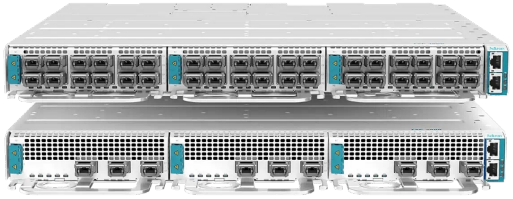
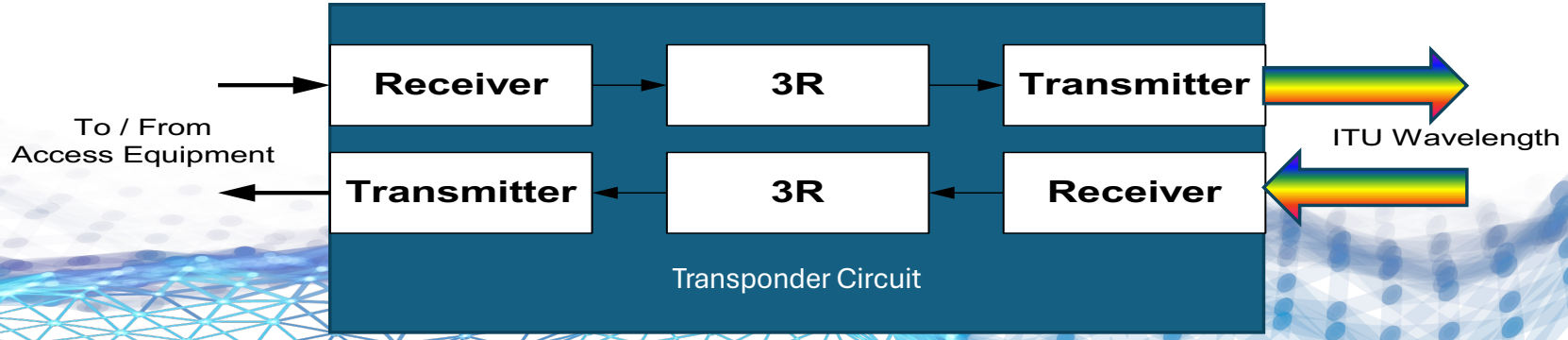
Transponders

- In WDM, a transponder is a device that converts the access input signal into a WDM specific wavelength and vice versa
  - Can be both CWDM and DWDM
  - Transmitter is very narrow WDM specific laser, typically
  - Receiver is broadcast detector (accept all WDM wavelengths)



- For each additional channel, an additional transponder is required



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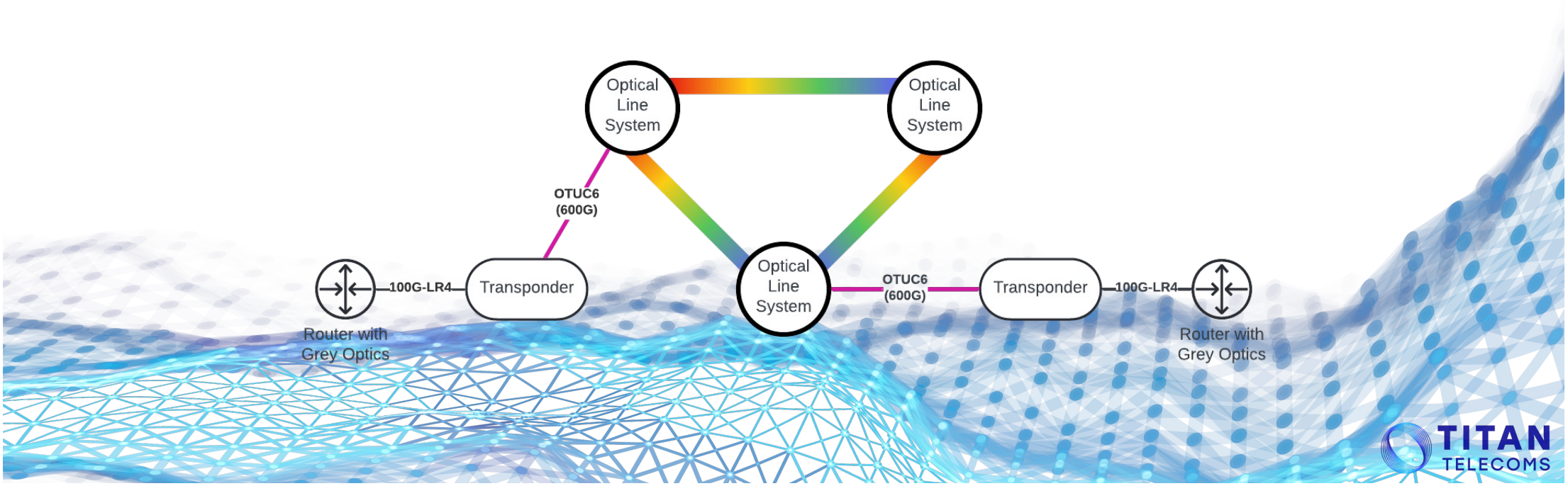
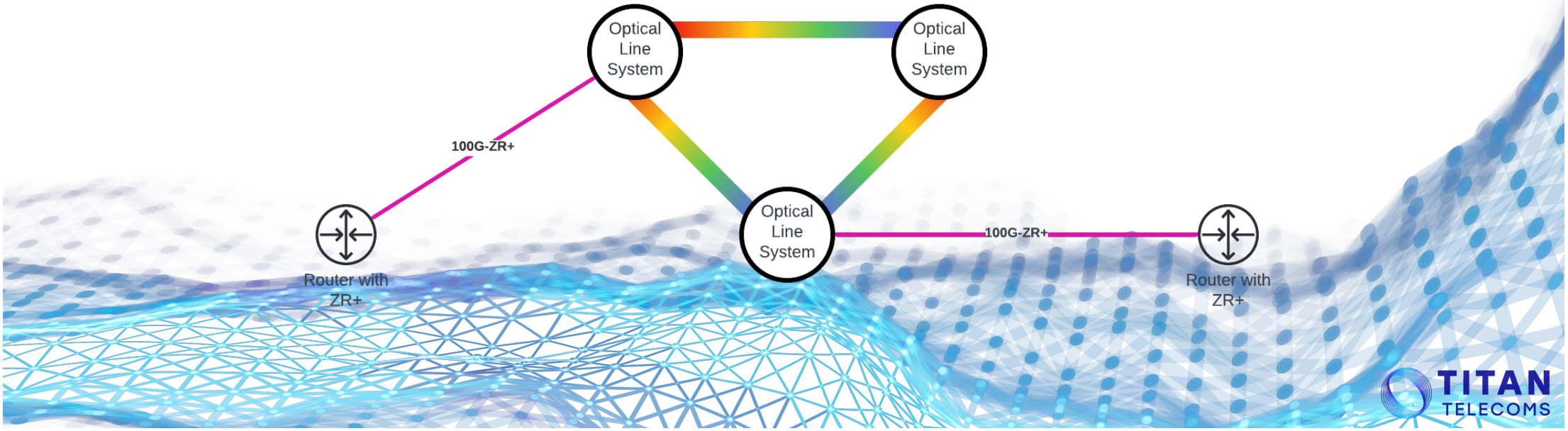
Transponder Example

- We have our Router connected to our Transponder
- Transponder is connected to a local optical node via multiplexer



Coherent Pluggables

- Cost Rationalisation through common pluggable leading to lower “Cost per Bit”
- Minimizing space and power costs due to removal of DWDM Transponders
- Short / Long Haul applications to allow for greater re-use



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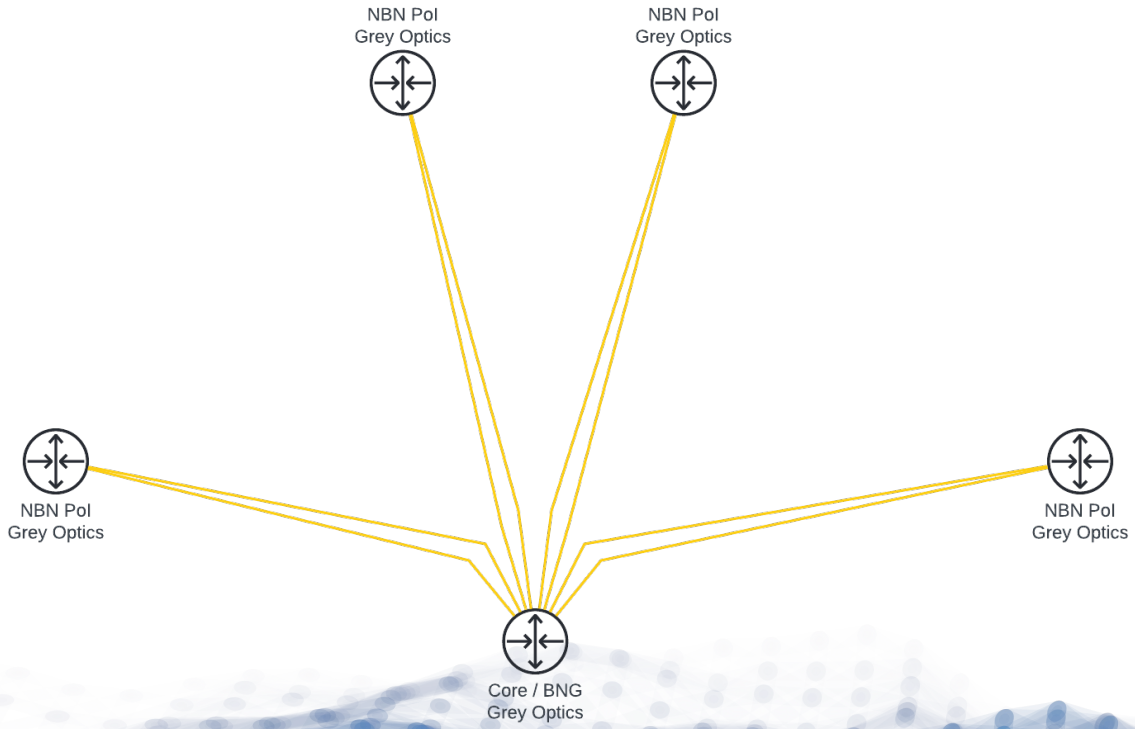
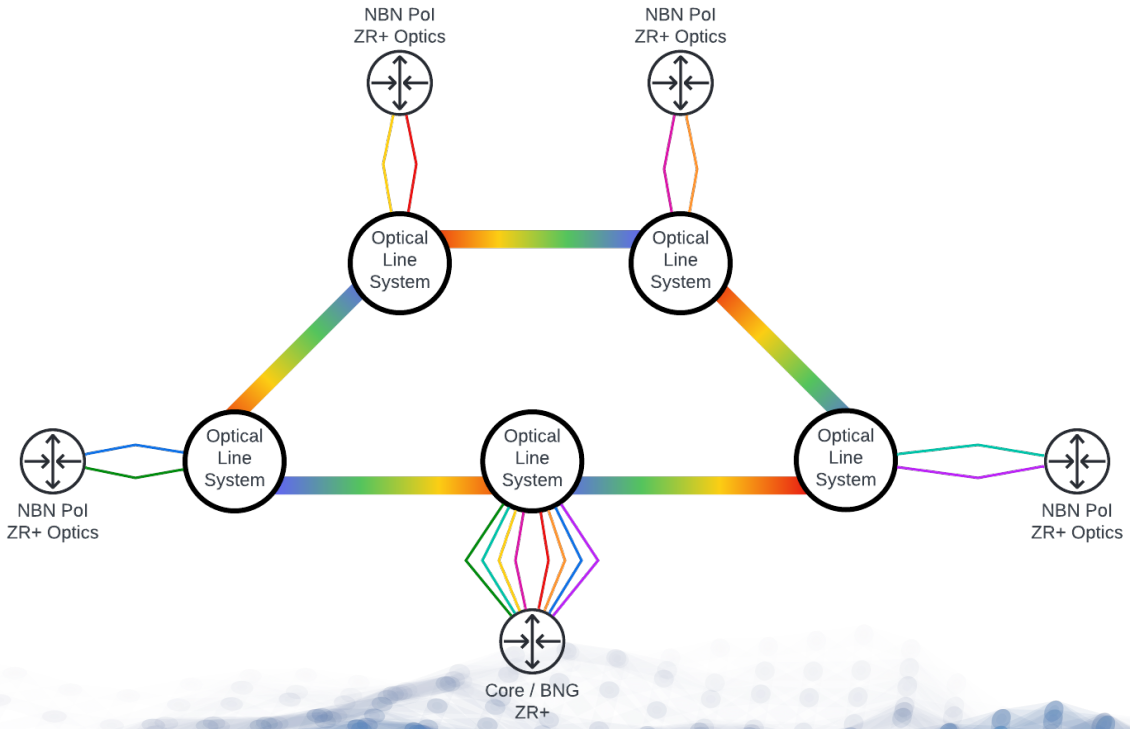
So how can we deploy?

Example Implementation



Example Implementation



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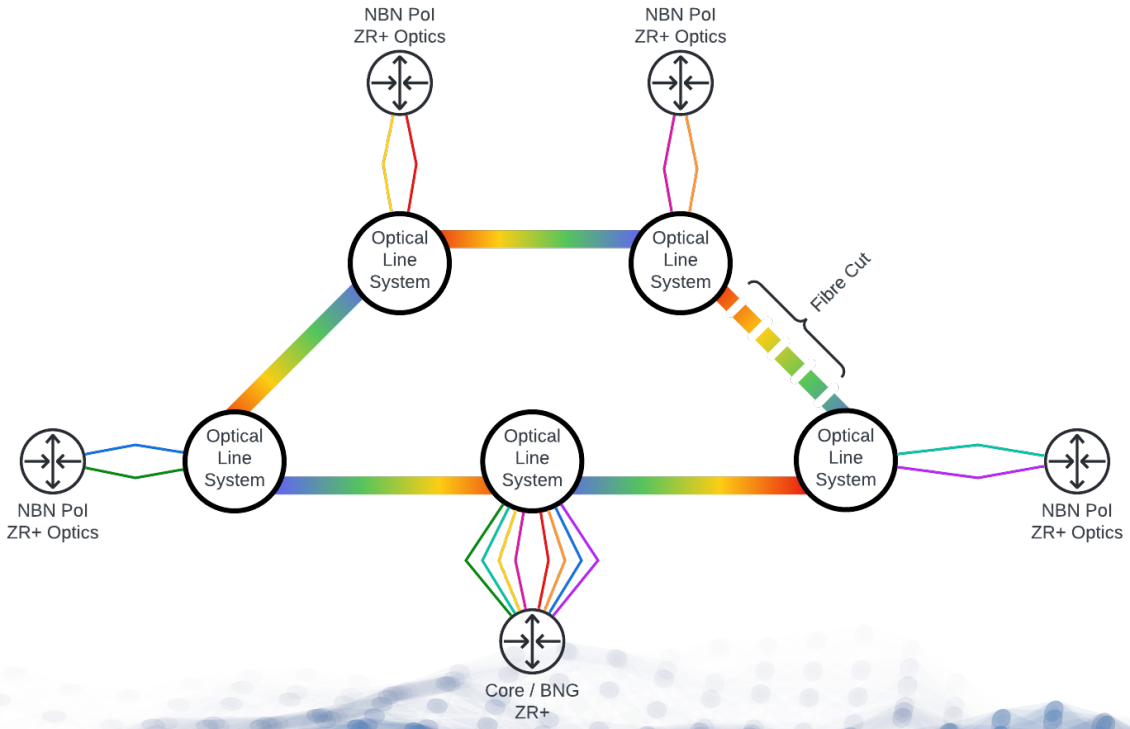
Example Implementation



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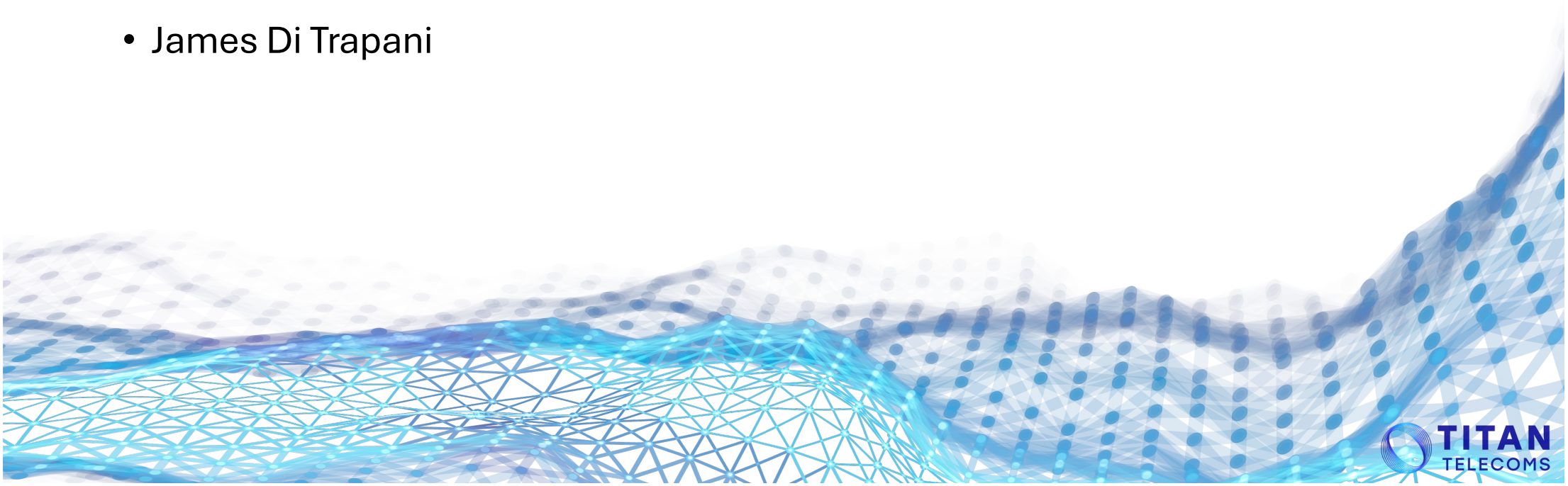
Special Thanks

- Team Titan
- Jonathan Mantel and Tony Thomas from ADTRAN
- Michael Hobl
- James Di Trapani

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