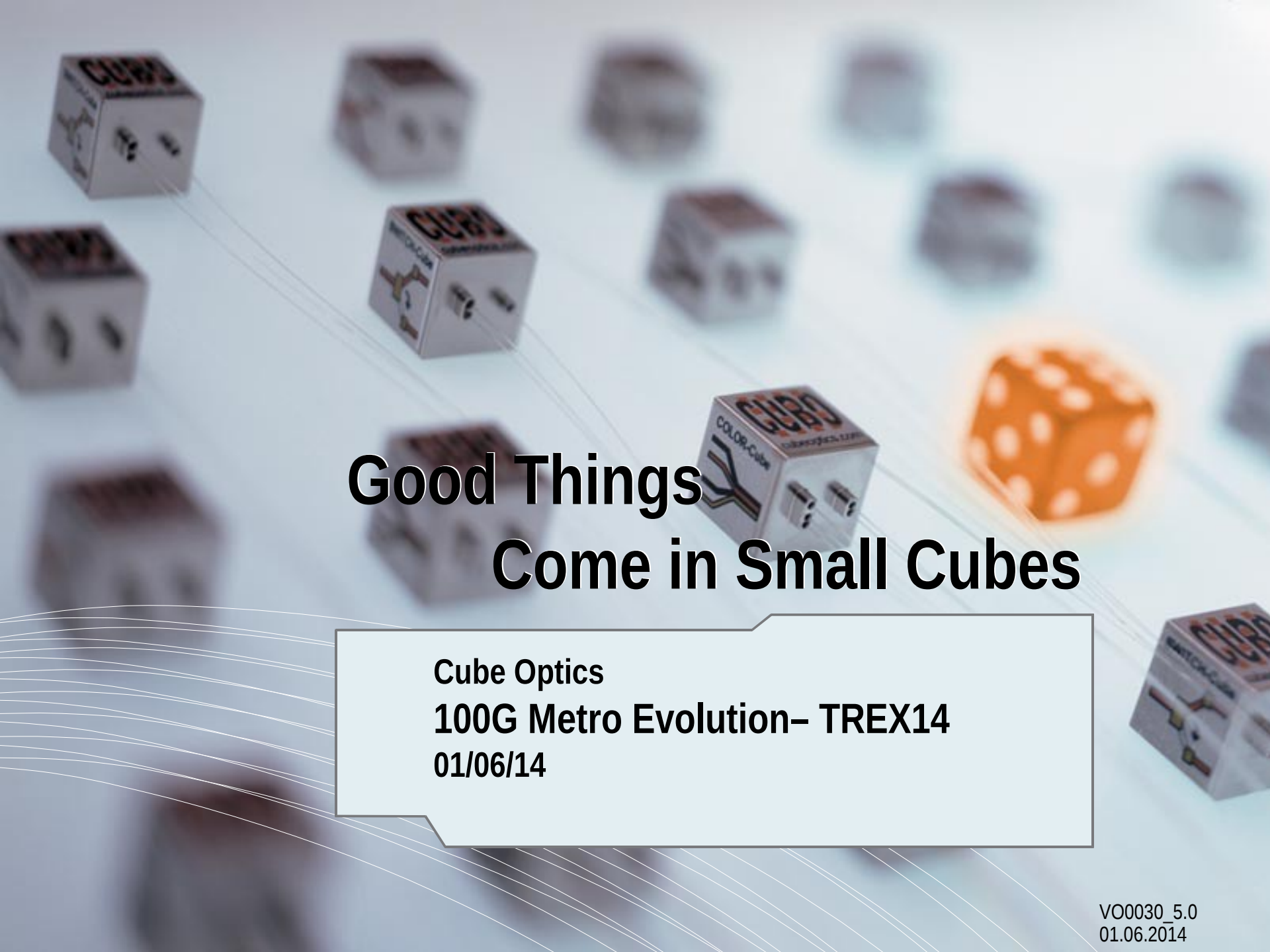


Good Things Come in Small Cubes

Cube Optics

100G Metro Evolution– TREX14

01/06/14

Before we start talking about 100Gig

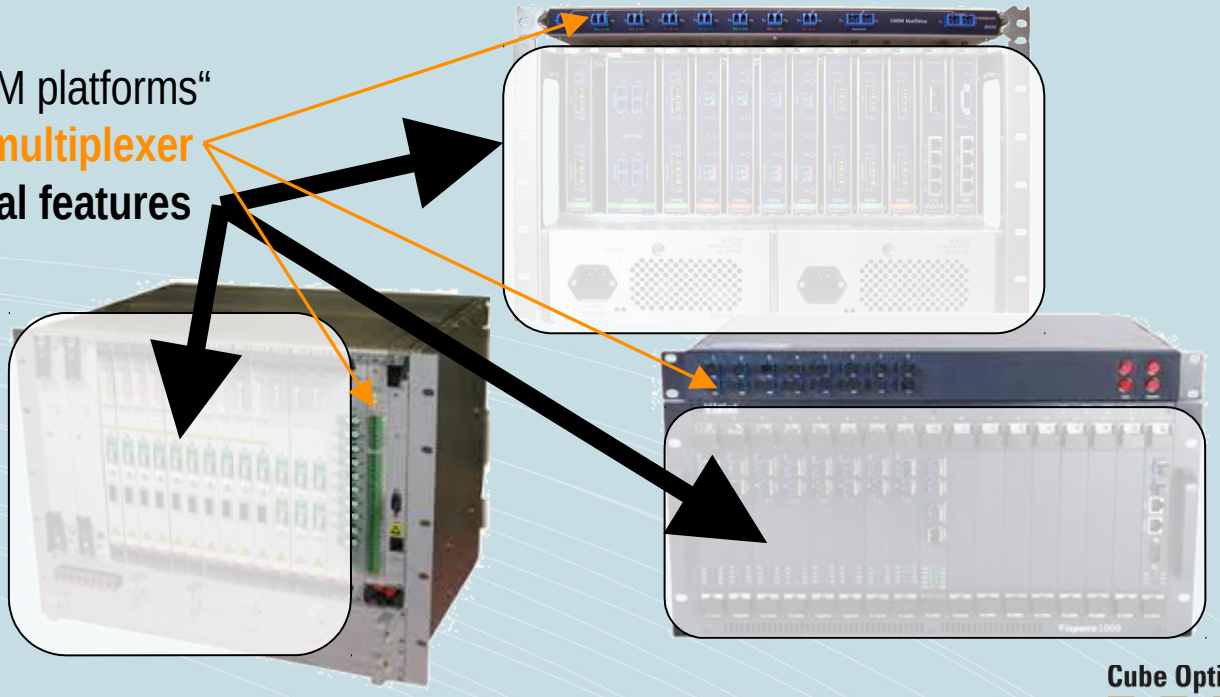
- Lets go back to basics and understand what we mean by WDM

……. to understand that the evolution to 100Gig, is similar to evolution to 10Gig

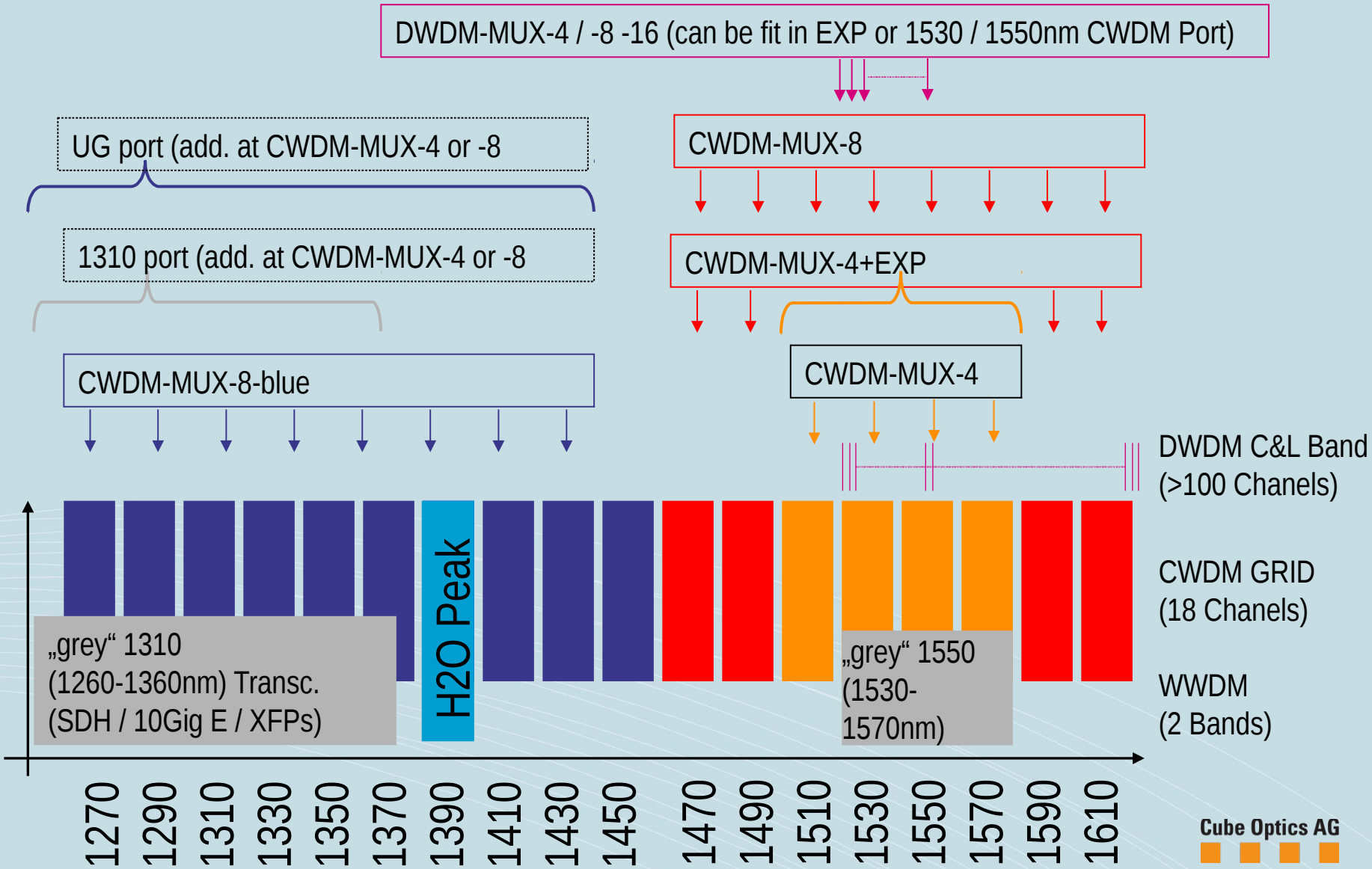
What is (D)WDM?

- ITU standardised grid of up to 100 channels of different optical lambdas (“colours”). Not more nor less!
- (D)WDM is NOT - nor requires - transponders, power supplies, monitoring, electrical aggregation (electrical muxponding),switching, media conversion, etc, but often this is bundled together with DWDM and sold under the misleading tag of “DWDM”.

Typical „DWDM platforms“
5% (D)WDM multiplexer
95% additional features



WDM grids



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CWDM vs. DWDM

CWDM

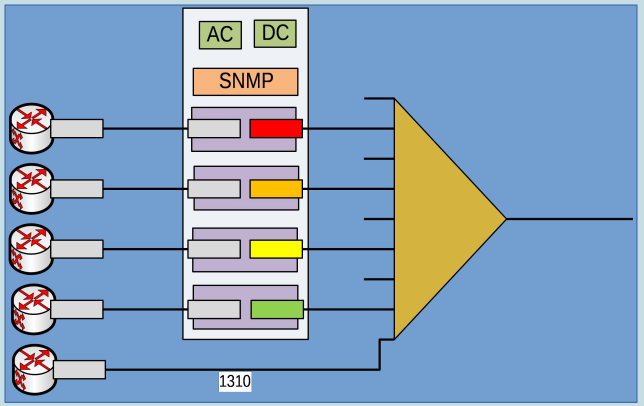
- Metro / Access networks
- Up to 18 channels (20nm spacing)
- 100Mbit – 10Gbps / channel
- *40/100G @1310*
- No amplification possible
  - 150km (1Gbps)
  - 70km (10Gbps)
- Lower cost muxes, much lower cost transceivers

DWDM

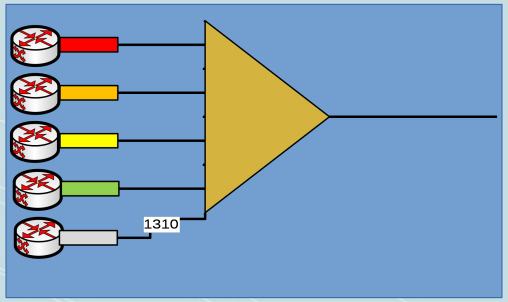
- Long Haul Networks
- Up to 80 channels (25 - 100GHz spacing)
- 1Gbps – 100Gbps / channel
- Amplification possible, enables “unlimited” (but expensive) reach
- Higher cost muxes, much higher cost transceivers

CWDM in Active v Passive CAPEX

- **Active CWDM System**
  - Conversion from client (“grey”) to line (coloured) signals by transponder cards
  - Active solution requires a chassis with power and management
  - ~ €12k

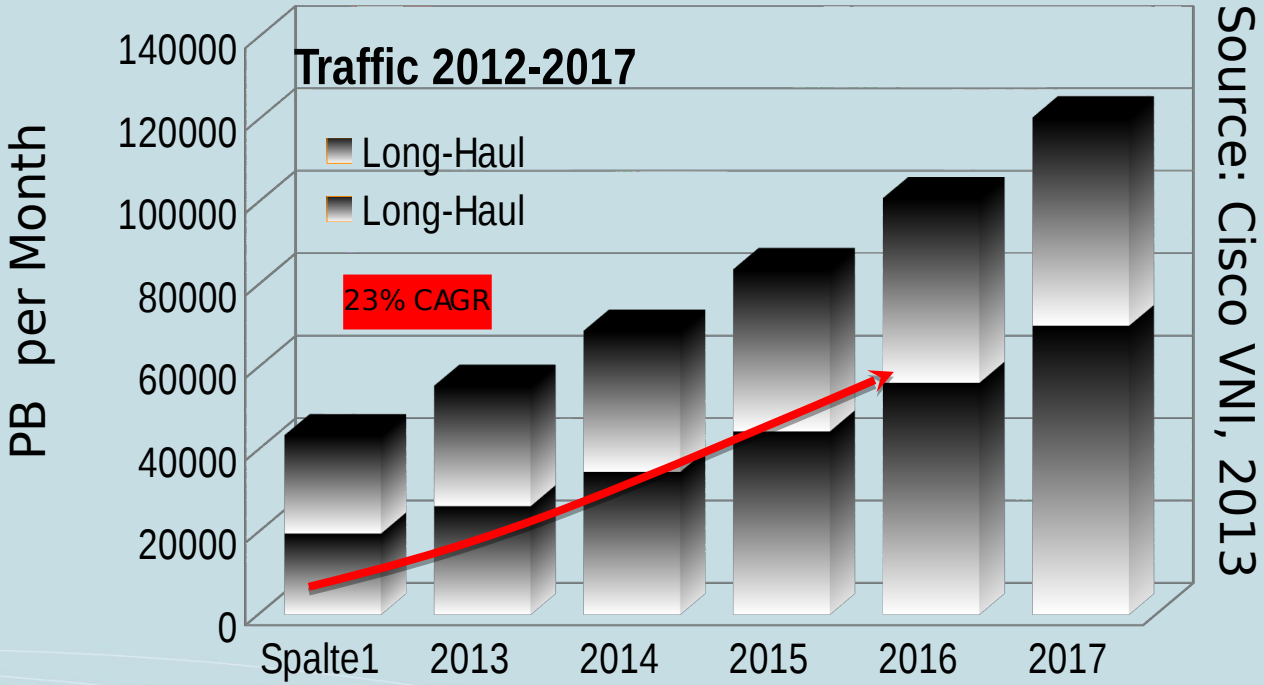


- **Passive CWDM System**
  - No extra signal conversion, transceivers plugged straight into terminal equipment
  - Transceivers / Resilience are managed by terminal equipment (Switch, Router, etc.)
  - ~ €3k



Example: 8 channels per fibre link, excludes transceivers

Metro traffic to grow 3x over next 5 years…



- Metro-only traffic will surpass long-haul traffic in 2014.
- Metro-only traffic will grow nearly twice as fast as long-haul traffic from 2012 to 2017.
- If you have a 40-channel 10G DWDM system filled at 50% capacity (= 200 Gbps) today, you will need to upgrade that system in the next two years

Is 100Gbps Today's Solution for Everything?

- NO! It depends…
- 100G price / bps is still (and will be for some time) higher than at 1G/10G
  - E.g. 100GBase-LR4 roughly 100x 10GBase-LR pricing ("only" ca. 40x at DWDM)
  - Higher complexity of 100G transport may add further cost (e.g. DCUs etc)
- So when does it make sense today / nearer term future?
- Andrew Schmitt from Infonetics, October 2013:
  "*It is only used (today) when service providers must use it, which means 1 of 2 situations:*
  - *insufficient fiber (and WDM) capacity to deploy more 10G traffic*
  - *a 100G private line service that needs to be delivered—a 100G router port that must be sent across the metro* "

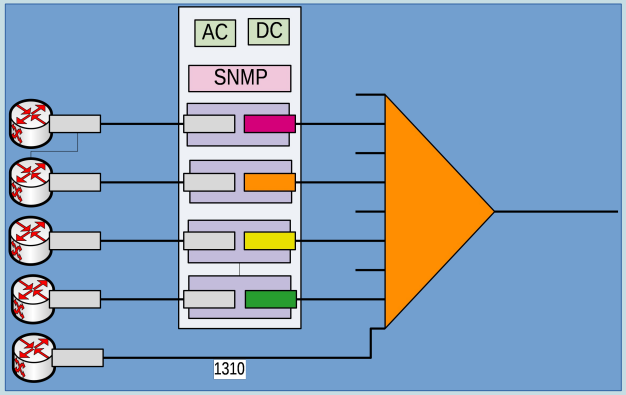
If You Need 100G Metro – Which Form is Best?

- **2 Different Transport Means**
  - Active versus Passive Transport
- **Competing transceiver / transponder technologies**
  - Coherent versus Direct Detection

Active vs. Passive Transport

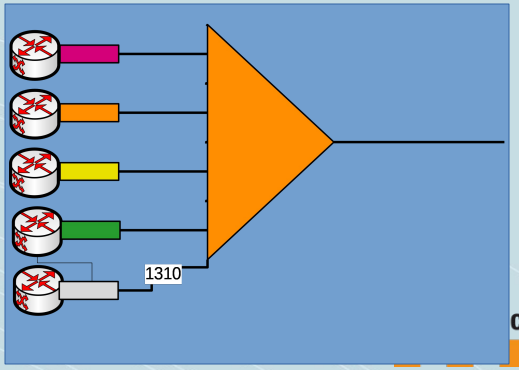
Active Transport

- Conversion from client (“grey transceivers”) to line (“colored transceivers”) signals by transponder cards
- Requires additional hardware: transponder cards, power supplies, management cards (+ software)
- 3x amount of transceivers required



Passive Transport – ca. 50% lower CAPEX & OPEX

- No conversion, transport transceivers are plugged straight into terminal equipment
- Less active elements => higher reliability, less latency
- Transceivers are managed by terminal equipment (Switch, Router, etc.)



Coherent vs. Direct Detection (Pluggables)

Coherent

- Developed for Ultra-Long Haul, adaption for metro
- Complex phase & amp modulation, hence less less sensitive to CD & PMD so wider reach
- 1 lambda per 100G used
- NOT available as pluggable, “street” availability not before 2016 (cost remains a BIG challenge)

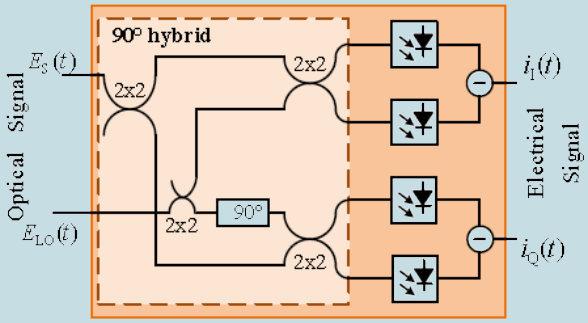
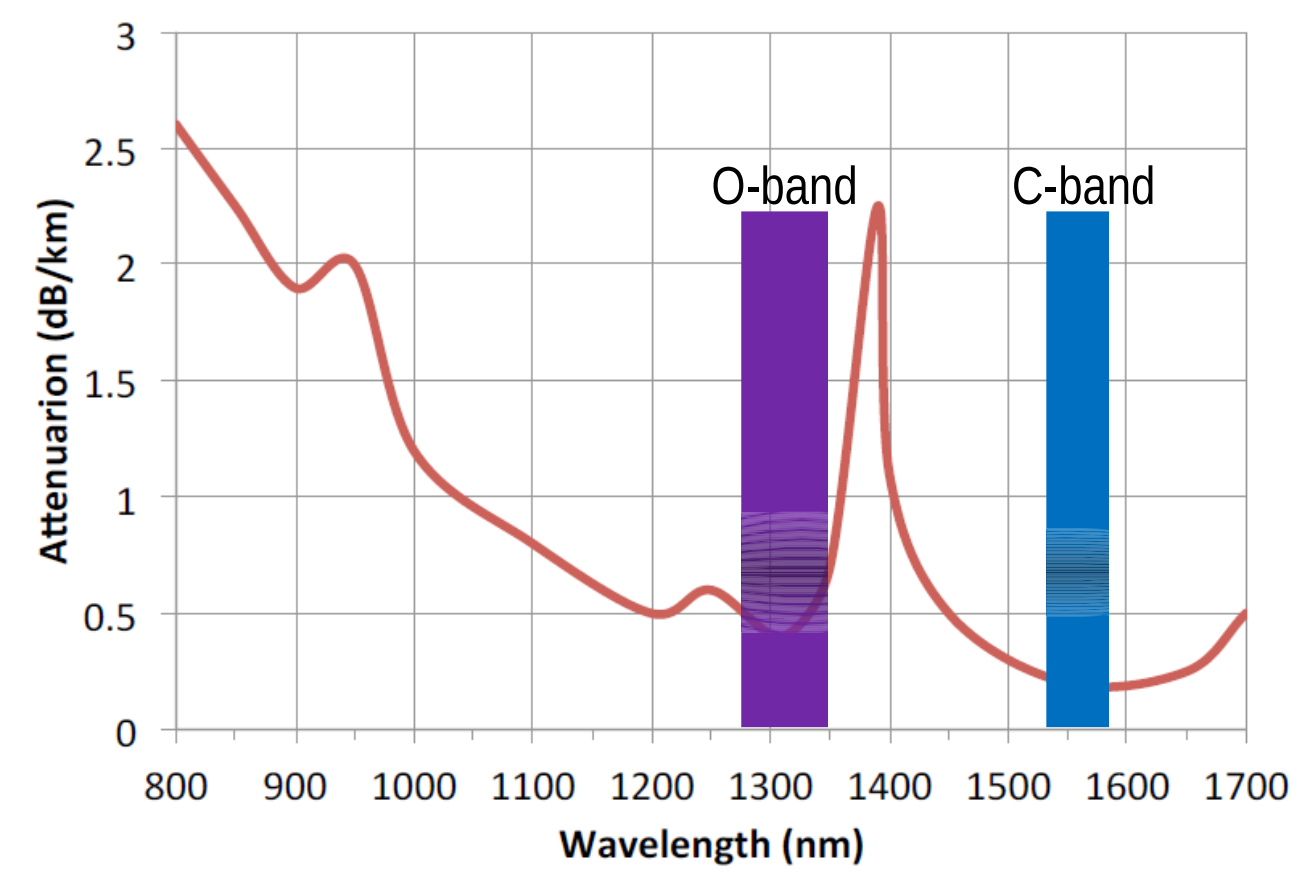


Figure 2: Coherent detection using optical 90° hybrid and balanced photodiodes

Direct Detection

- Emerging from LR/ER (10-40km) Datacom
- Based on simpler PDs, reach limited by CD & PMD
- 4 lambdas per 100G used
- Produced by >5 module makers in 100Ks since 2011

Transmission Window‘s



Single Circuit 100G over O-band

Requirements

- 100GBase-LR4 transceiver module
  - Transports 4x25Gbps via integrated optical 4 channel (de)mux
  - One single mode duplex fiber
  - SC/PC connectors for SMF fiber pair
  - Reach < 10km

- *SOA Semiconductor Optical Amplifier*
  - Extends the reach of 100GBase-LR4 transceivers up to 80km
  - Very good BER of 10^{-16} at >50km

Powering ca. 50+ x 100G links in European and US metro regions, e.g. at AMSIX, NETNOD

100Gig LR4 ~ 52km

NETNOD - COMIX 100Gig

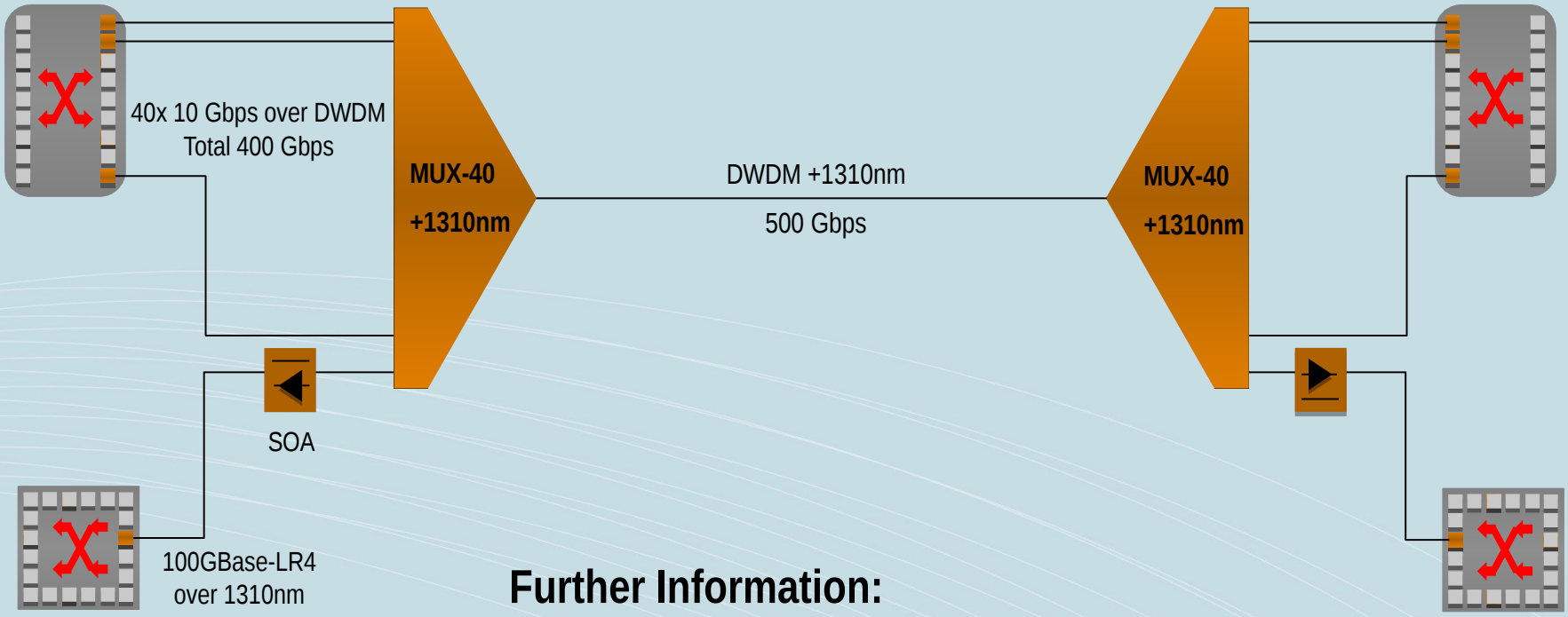
http://blog.cubeoptics.com/index.php/aH8

100G Passive Metro Network Architectures

	100G in O Band		100G in C Band	
	Single Circuit 100G	10G DWDM + 100G overlay	10G DWDM + 100G DWDM overlay	100G DWDM
Maximum capacity	**100 Gbps** (= 1*100G)	**500 Gbps** (= 1*100G+40*10G)	**1.6 Tbps** (=12*4*25G+40*10G)	**2.4 Tbps** (= 24*4*25G)
Number of wavelengths	1	41	88	96
Number of transceivers	1	41 (1*100G, 40*10G)	52 (12*100G, 40x 10G)	24 (24*100G)
Maximum distance	10 kms (no amp) Up to 80 kms (SOA)	<10 kms (no amp) Up to 80 kms (SOA)	~10 kms (no amp) 10-100 kms (EDFA)	~10 kms (no amp) 10-100 kms (EDFA)
Typical transceiver	CFP 100GBASE-LR4	CFP 100GBASE-LR4	CFP DWDM (direct detect)	CFP DWDM (direct detect)

Overlaying 10G DWDM with 100G (O-Band)

- Up to 40 DWDM channels at 10G - Additional 100G link over 1310nm O-Band
- Optional 100G LR4 reach extension via SOA
- Up to 500Gbps per fiber pair



Further Information:

http://www.cubeoptics.com/evolution1310_

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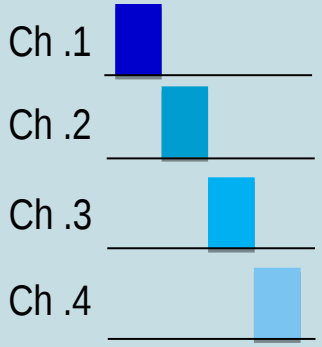
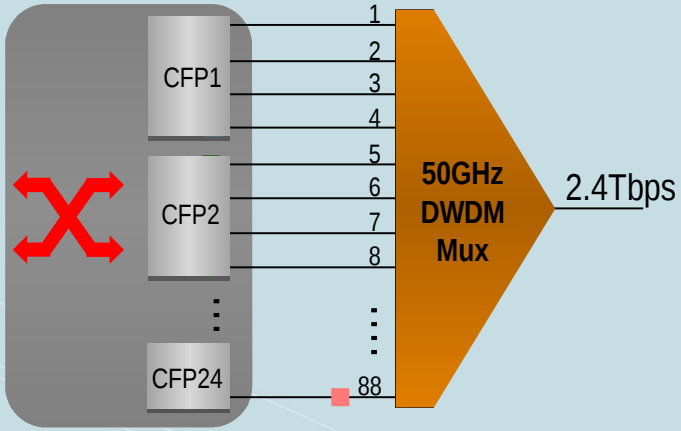
100G DWDM over C-band

Requirements

- *100Gbps DWDM CFP transceiver module*
  - Transports 4x25Gbps.
  - Four single mode duplex fibers.
  - Employs 4 tunable lasers in the 50GHz ITU-T channel grid (DWDM) and 4 receivers.



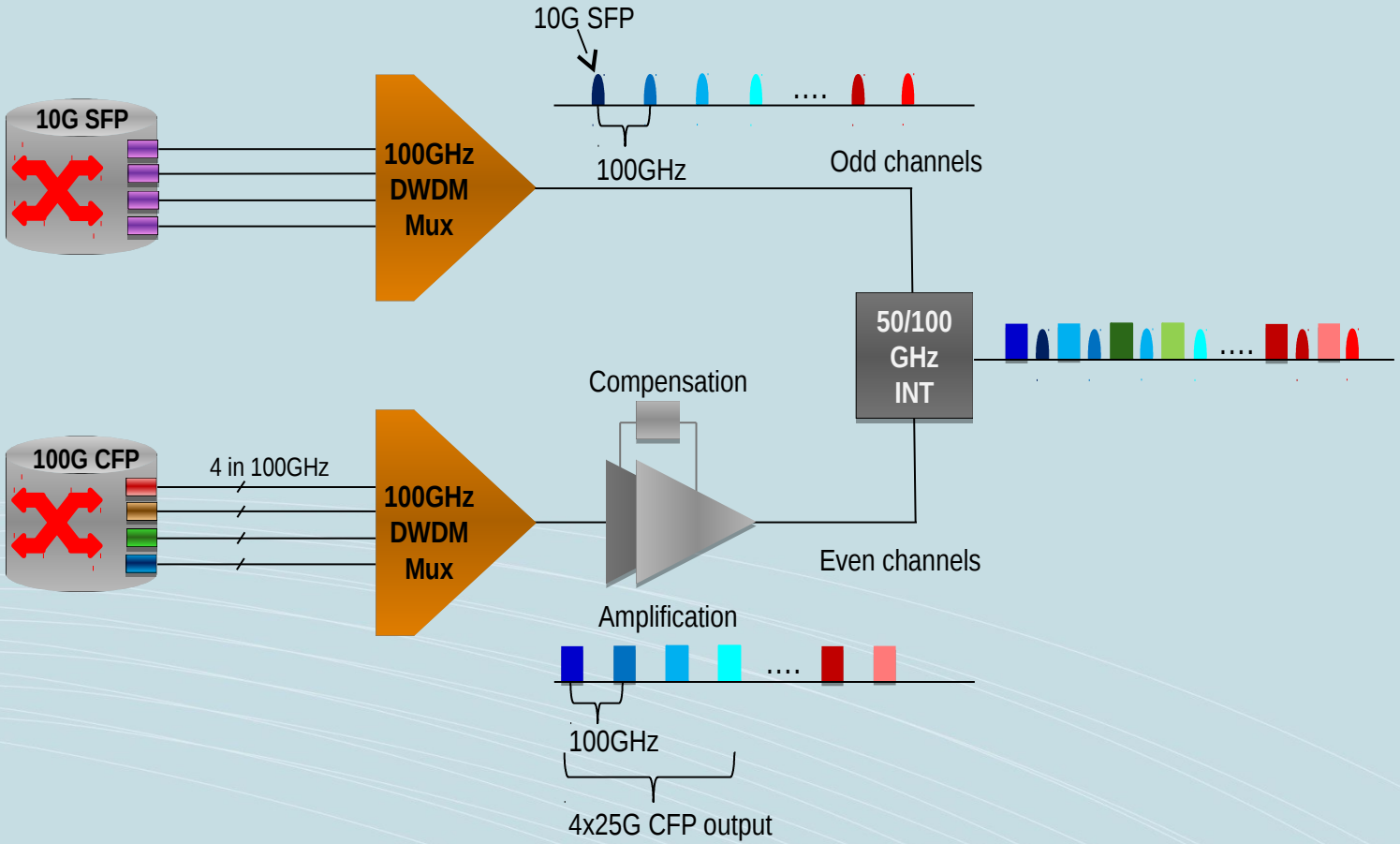
- *96 Channel DWDM multiplexers/demultiplexers*
  - Passive DWDM mux/demux with 50GHz grid over a single mode fiber pair.
  - Up to 24 "differently colored" 100Gbps DWDM CFP transceivers can be transported via a 96 channel MUX



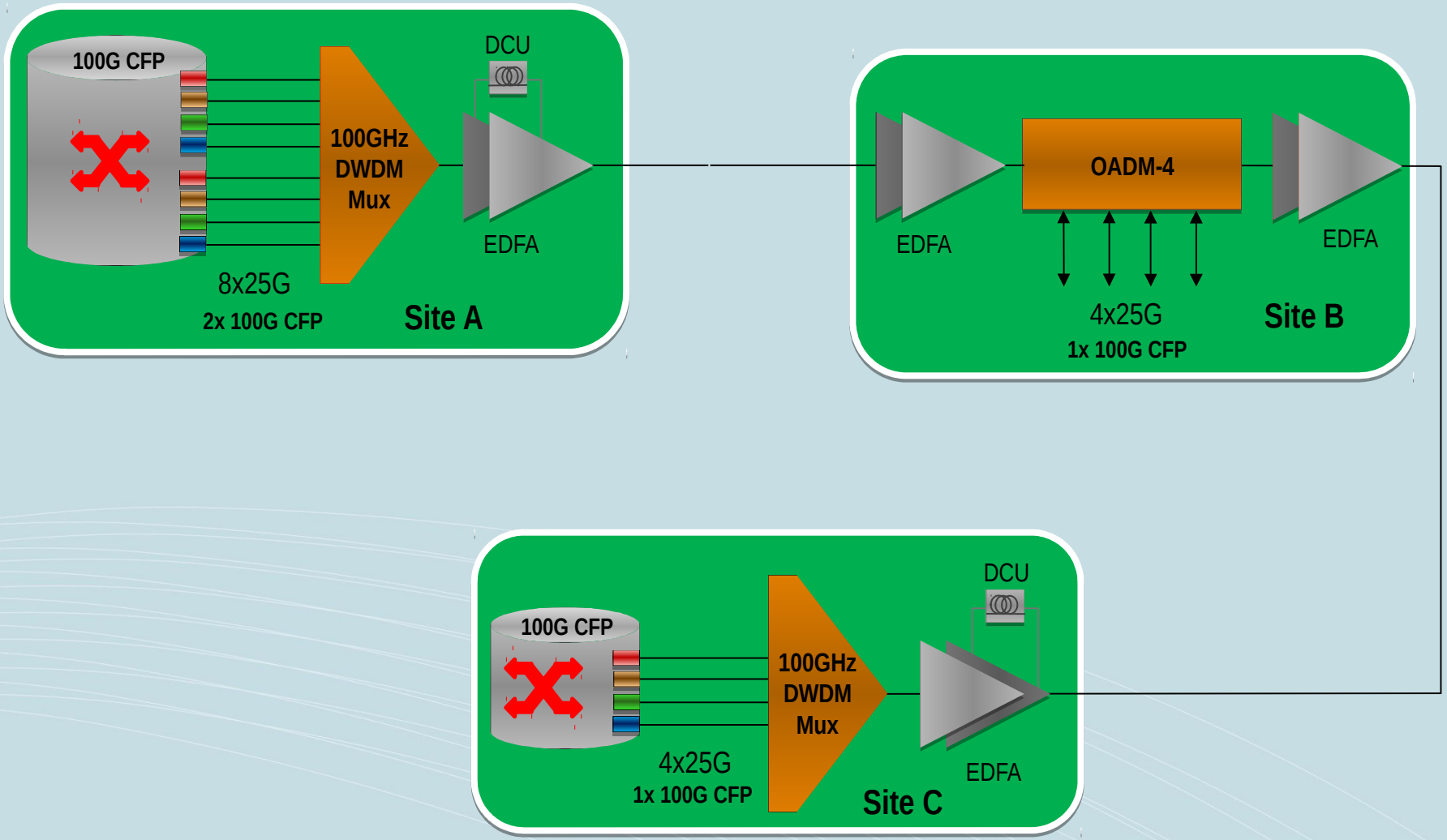
- Reach extendable with standard, stand-alone ***EDFA***s to >100kms

Overlaying 10G DWDM with 100G (C-Band)

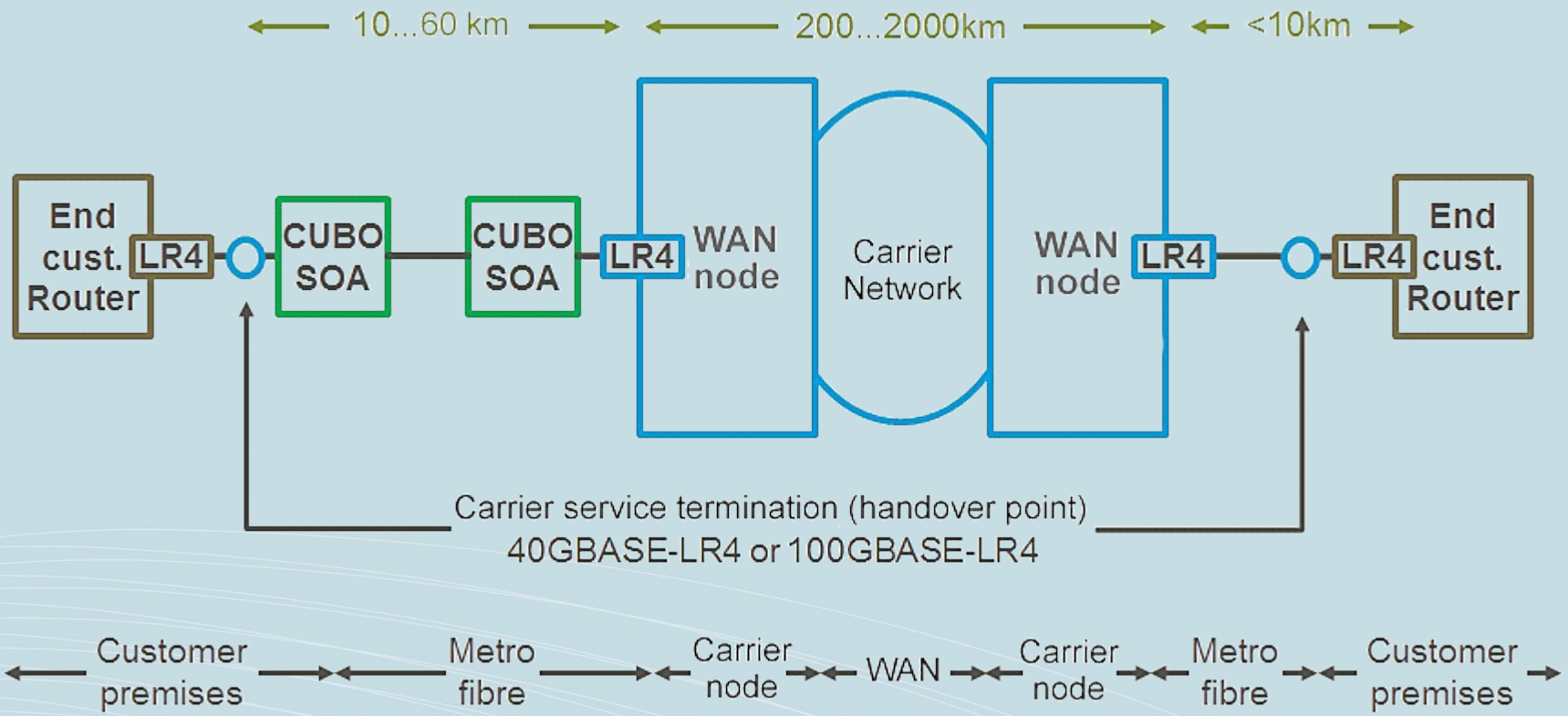
- Complementing the existing 10Gbps DWDM system with 100Gbps upgrades



100G OADM example scenario



Extending the Reach of 100G



Multiple 100G DWDM in non FEC environment

- **Results**
  - 0-70km reach without central location for multiple 100G DWDM services in 100GHz grid. Different setups shown
    - (20km, 40km and 60+km)
  - Possible upgrade up to 22x100G on a fiber pair
  - Proven to work with existing DWDM 10G with matching power levels on 10G / 100G paths
  - Transceivers were tuneable by end customer switch.
    No additional signal conversion or transponder card were needed as DWDM Transceivers are directly plugged into the switches
  - Small setups on short distances only need the Muxes and Transceivers (no DCU, no EDFA, no interleaver).
  - Long term stability over temp 20-50°C (cycled) running stable over 350hrs (2 weeks)
  - Tested and compatible to Brocade and Alcatel environments
    - To be tested in Juniper and Extreme environment in 2014

Conclusion

- 100Gbps is still not making sense for all Metro connections but has become a valid solution for fiber constraint areas and native 100G port transport
- 100Gbps Passive Transport has become a powerful, simple and low(er) cost alternative to NEM based Active Transport Solutions

- Coherent Pluggables may become a good alternative to Direct Detect Pluggables, but realistically not deployable before 2016

Further Information: http://www.cubeoptics.com/evolution1550_

We look forward to providing you with further information.

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