Real world systems

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ADVANCE

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The real world

- History
- Practical fiber optical systems – what are the realistic variants
- Limitations
- Tradeoffs between performance and cost
- What do I need to require from my plant to build a system?
- Real world System examples
- Future development

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History 1(2)

- **Initial battle ’92-’93**

  DWDM or 10 Gbit/s…

- **Product definition phase ’94-’95…**

  1. Discrete subsystems bolted on to SDH/SONET machines?

  Resulted in: Nortel became no 1 by supplying passive filters and amplifiers to 10G systems

  2. DWDM systems with well defined interfaces (transponders)?

  Resulted in: New companies borne (e.g. ADVA & Ciena). Datacomm people started to smell the opportunity (The big fat pipe networking philosophy)

  3. The all optical madness… (even down to logics)

  Resulted in: Lots of perfectly good money wasted…

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History 2(2)

- **The middle age of optics (~'96-'00)**
  DATACOMM: IP over Optical. More routers! Less functionality in transport layer! Cheap big fat pipes… Transparency rules!

  TRANSPORT: TDM functionality integrated in DWDM systems. Ethernet becomes a transport technology.
  SDH transformed (from focus on products to focus on transmission technology)

- **The modern age (Year 2000 and beyond)**
  - DATACOMM and TRANSPORT remarried.
    Why? Answer: real time IP services (fewer routers, more transmission)
  - More functionality in Transport networks (G709, GFP, GMPLS etc.)
  - Focus on Ethernet
  - (C)WDM in feeder/access network. Why? DSLAM backhaul & corporate data service.

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Practical systems, realistic variants 1(2)

- Unamplified CWDM systems
  - Reach 0-100 km
  - Capcity typically 80 Gbit/s
  - Cost factor (per 10 G channel) = 1
- Unamplified DWDM systems
  - Reach 0-130 km
  - Capcity typically 320 Gbit/s
  - Cost factor (per 10 G channel) = 1,3
- Amplified Regional transport systems
  - Reach up to ~600 km
  - Capacity typically 640 Gbit/s
  - Cost factor (per 10 G channel, assuming 2x5 amp stages)
    First wave: 35
    Last wave: 1,4

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Practical systems, realistic variants 2(2)

- Amplified Long haul transport systems
  - Reach up to ~1000-1500 km
  - Capacity typically 640 Gbit/s
  - Cost factor (per 10 G channel, assuming 2x10 amp stages)
    First wave: 62
    Last wave: 3

- Extreme applications. Ultra long haul, sea cable etc.
  - Reach up to ~1500-4000 km
  - Capacity typically 640 Gbit/s
  - Cost factor (per 10 G channel, assuming 2x20 amp stages) (*
    First wave: 630
    Last wave: 40

*) excluding installation ~20%

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Limitations

What is the key limiting factor for transmission systems:
Two answers required: Cost is one. The other is more tricky to answer.

In a practical world;

Attenuation -> Amplifiers

Amplifiers -> Noise

Noise -> Bit errors

Furthermore;

Dispersion -> Dispersion compensation

DCF -> More amplifiers

More amplifiers ->More noise

More noise ->More bit errors...

More powerful amps (?) -> Non linear effects

Non liniarities -> compensation methods (laser dithering)

Etc. Etc.

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Limitations (continued).

- In summary; An amplifier based transmission system is analogue by nature. Proper design tools and models is a must!
- One parameter that is not easily compensated for (today) is Polarization mode dispersion (PMD)
- PMD effectivly means that light of different polarization angle travel at different speed in the fiber = dispersion
- PMD is caused by e.g. Microbends/physical strains on the fiber (which causes a non circular core). Microbends could be caused by events extrnal to the fiber plant (e.g. A train causing vibrations in the ground or changes in temperature). Such events are statistical, thus PMD is a statistical phenomena.

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Limitations (continued).

- Thus, maximum PMD is specified as an average, and an average over a link (end to end)
- A Maximum PMD of X will mean worst case Bit Error Rate (BER) of Y, over a maximum of Z percent of the time
- Effectively; PMD is a limiting factor in 10G transmission systems, and the limiting factor in 40G transmission systems

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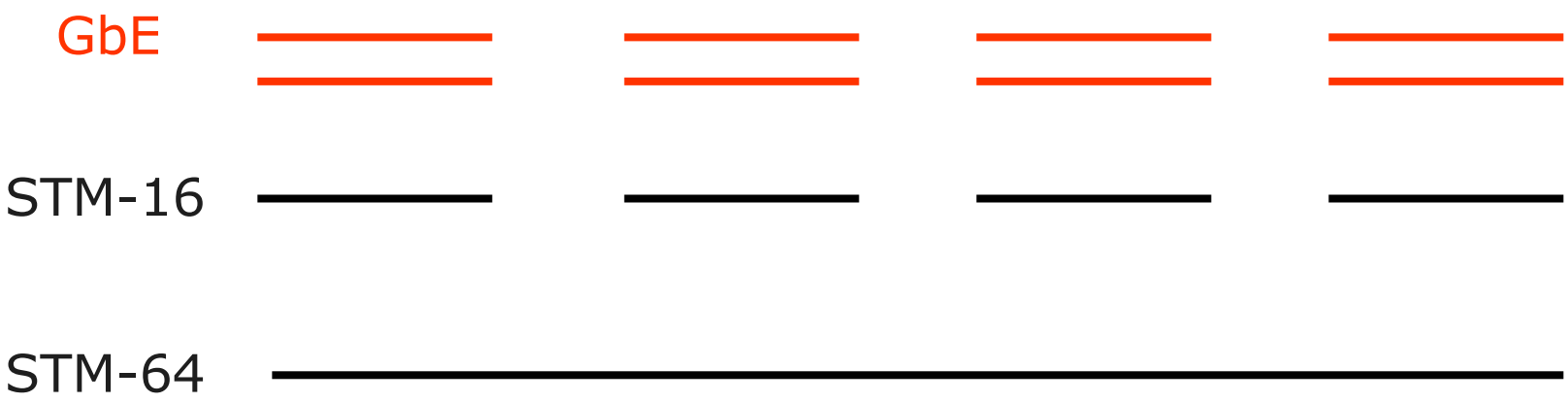
Tradeoff cost vs. performance

- Example network

- Traffic matrix



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Solution 1. DWDM Maximum capacity 32 waves, OADMs + Amplifiers

- Example network (60km between sites)

- Implementation details;
  - Only Single stage 18 dBm amplifiers
  - Group splitter (32 wavelenghts into 8 groups of four wavelenghts)
  - One group used for express, one group used for drop traffic
  - Dispersion compensation
  - Hit-less upgrade to 32 x 10G

Solution 2. CWDM Maximum capcity 8 waves, point to point OTMs

- Example network (60km between sites)

- Implementation details;
  - 8 Channel filters in all nodes
  - 10G regenerated in each node (!)

Comparison

- CWDM solution excluding 10 G. Cost = 1
- CWDM solution including 10 G. Cost =2,1

- DWDM soltuion excluding 10 G. Cost = 3,8
- DWDM solution including 10 G. Cost = 4,1

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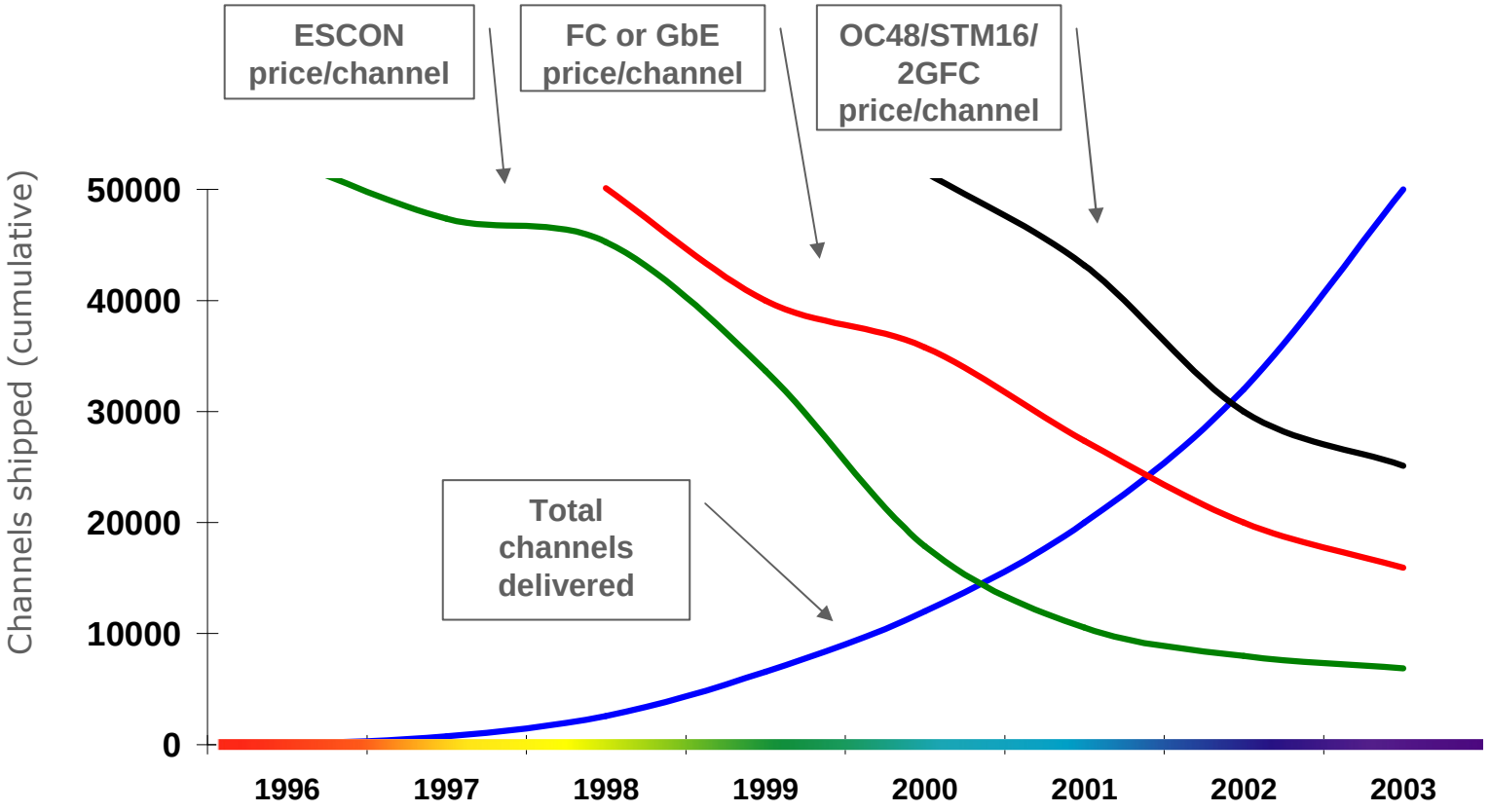
Reducing cost and increasing performance



Source: ADVA Optical Networking WDM products

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Requirement on fiber plant

- As demonstrated in this presentation, dB's cost money.
- Some advice;
  - Work with real values
  - Include fiber margin only
  - Equipment margin is the responsibiliy of the supplier

X dB can cost Y EUR, X+1 dB can cost 2Y EUR
(or simply be impossible)

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Fiber plant qualifiction

- Fiber type. Likely to be OK (G.652x or G.655)
- Attenuation. Use Optical Time Domain Reflectometer (OTDR)
- For CWDM, any reason to expect abnormal behavious at 1470-1490? If yes, qualify.
- Dispersion, normally not an issue, no need to characterize
- PMD if fiber is old (mid 90s and older). Available methods:
  - Fixed Analyzer (FA), using OSA
  - Interferometry (INTY) method, including both the generalized (GINTY) and the traditional (TINTY)
  - Stokes Parameter Evaluation (SPE) method, including both the Jones Matrix Eigenanalysis (JME) and the Poincaré Sphere Analysis (PSA).

Debated subject. What data can you get from your fiber vendor? If you cannot get data, measurement is a must!

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Other important items

- Patch panels
- Pig tails
- Fiber management
- Handling in General

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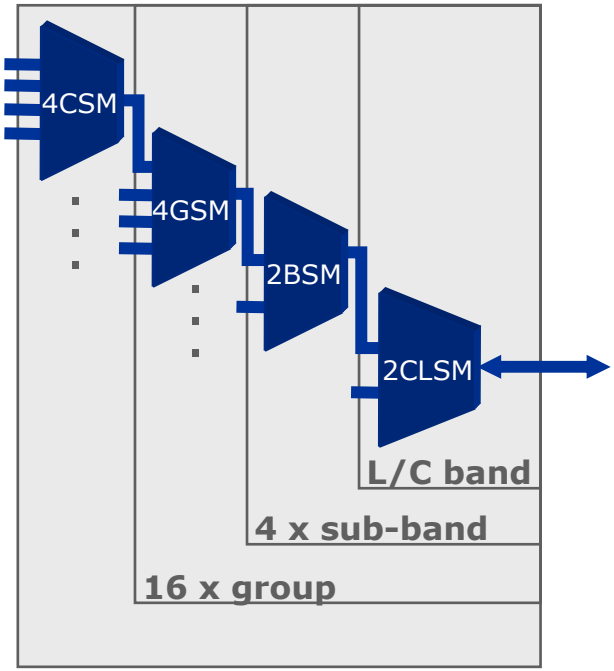
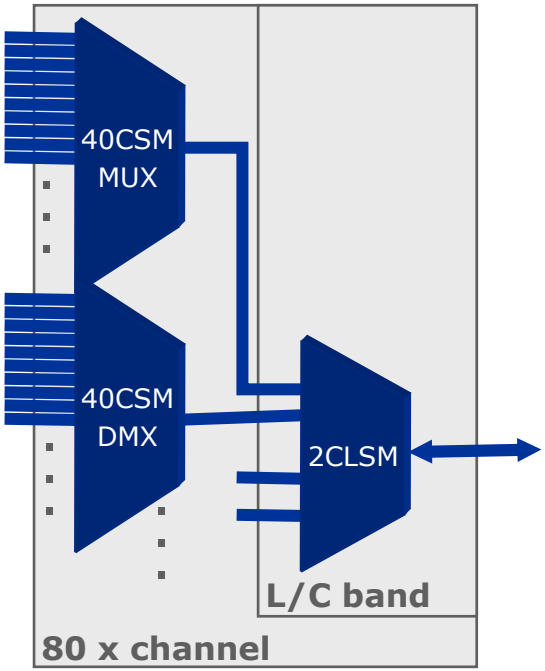
Principles of filter design

- Group filters or bulk filters





PRO (+)	Flexibility, cost	Lower loss
CONS (-)	Higher loss	Day one cost

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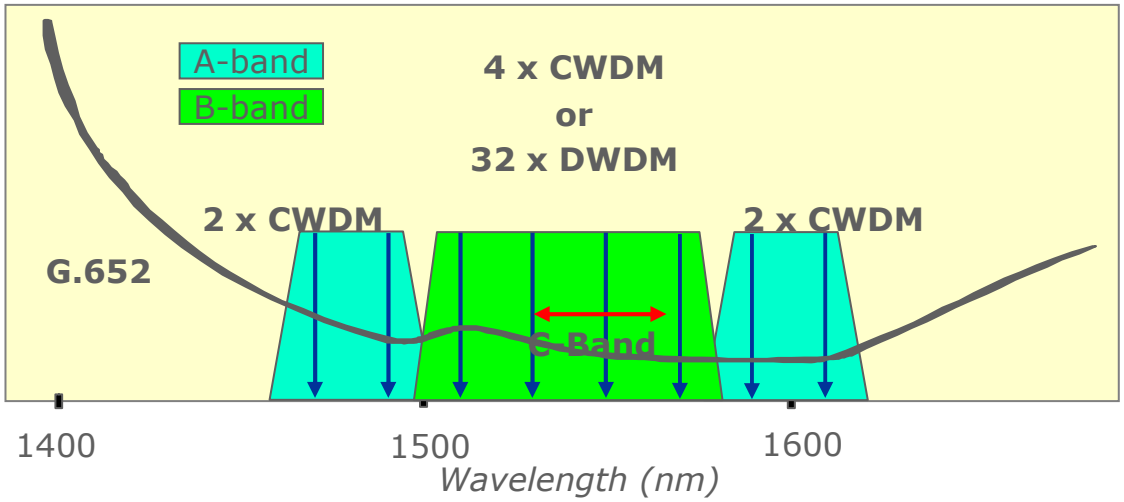
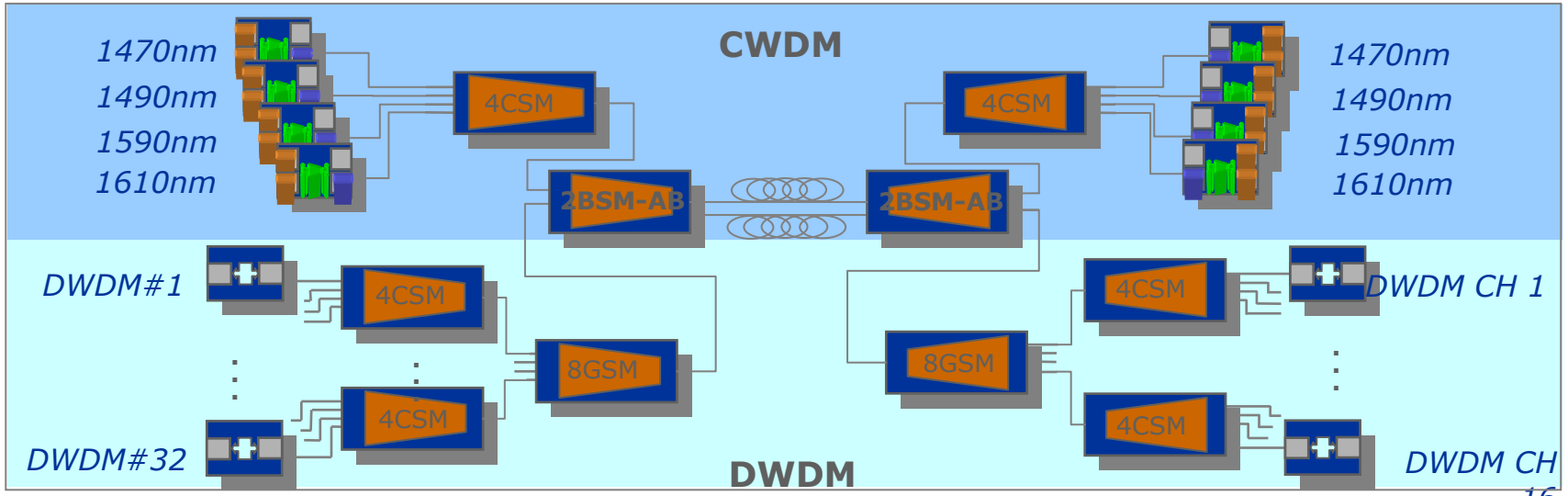
Hybrid C- and DWDM systems

- Band filter separating ”woofer/tweeter” waves from midrange
- Very flexible from upgrading perspective

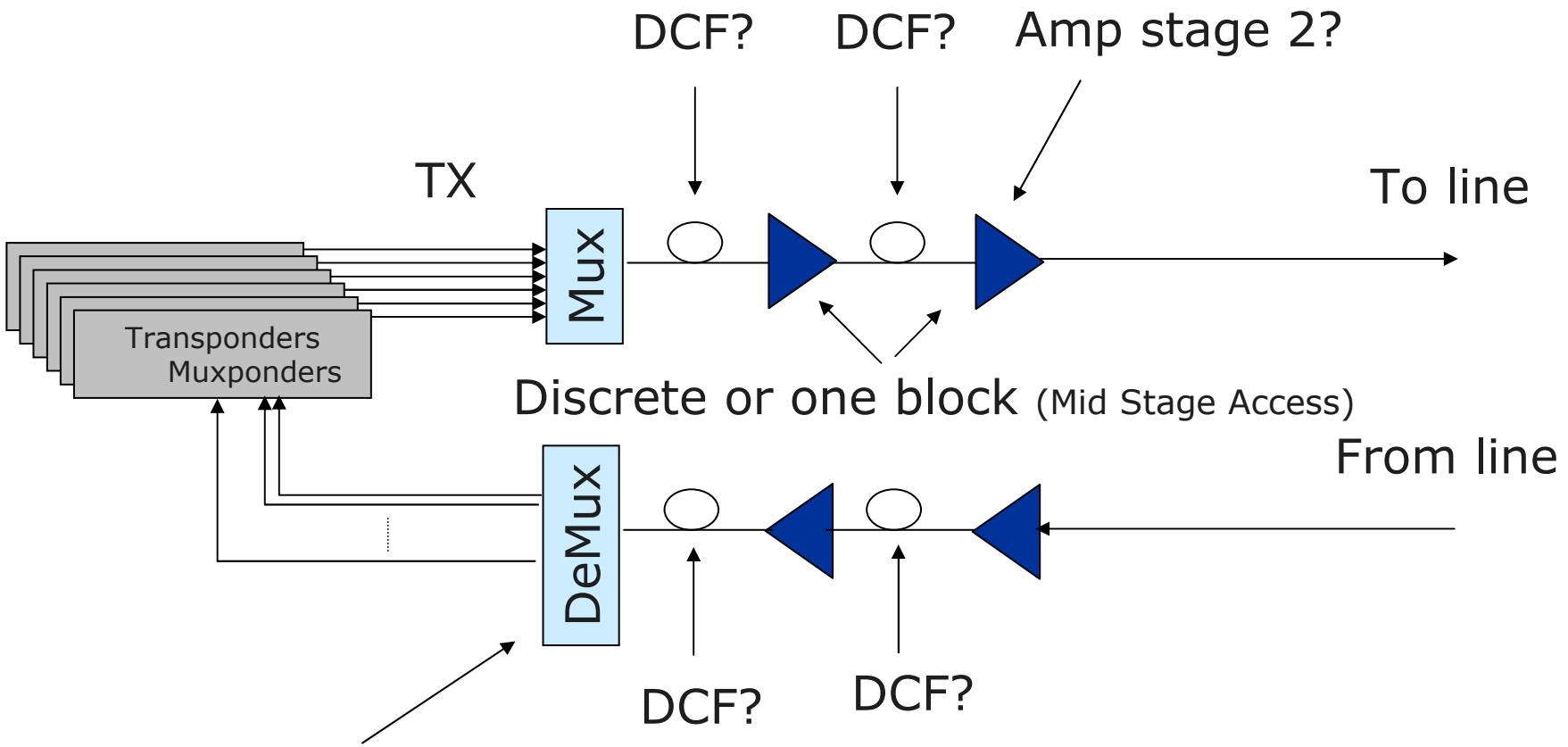


Example of Hybrid 4xC + 16 x DWDM

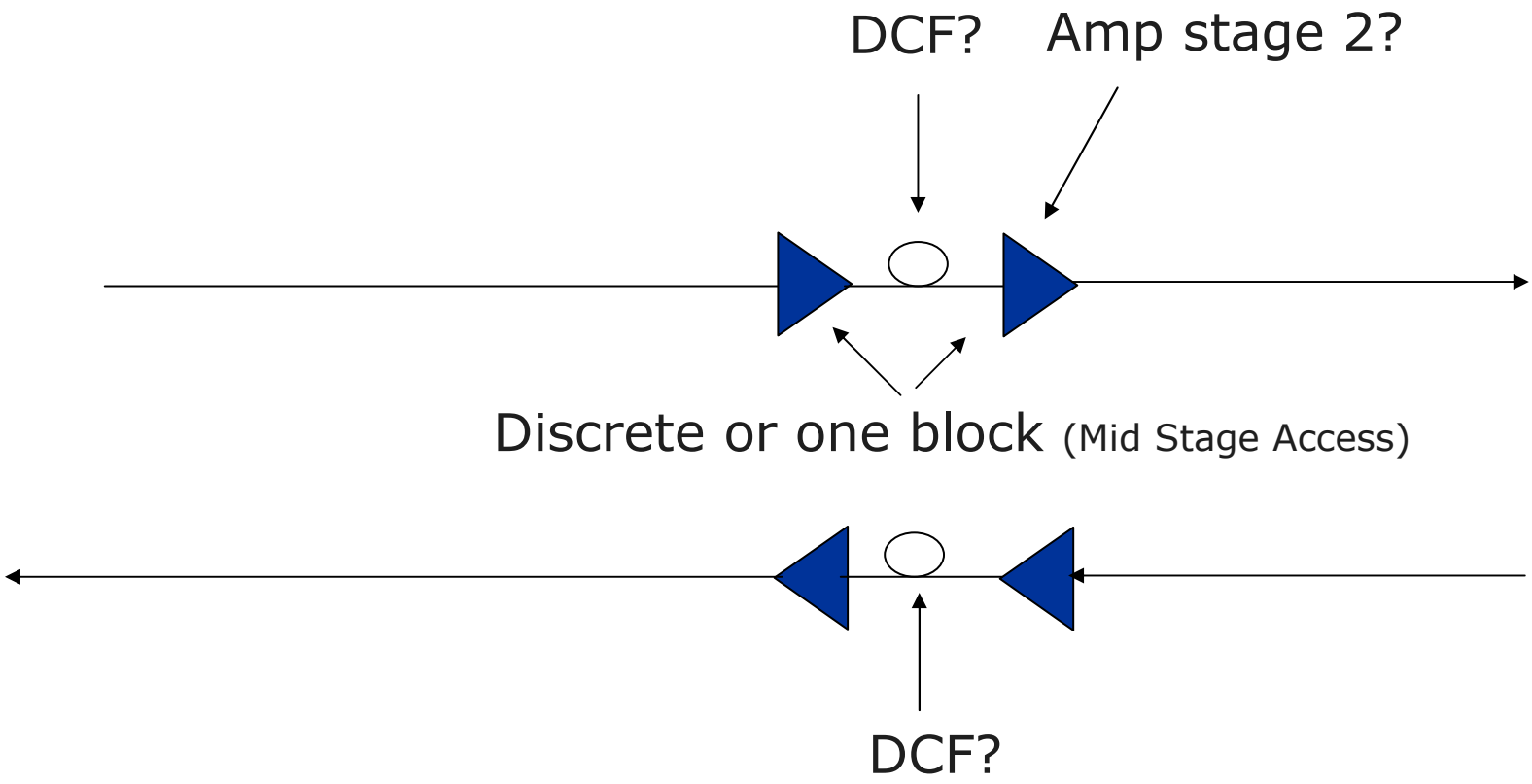
- Minimum planning day one



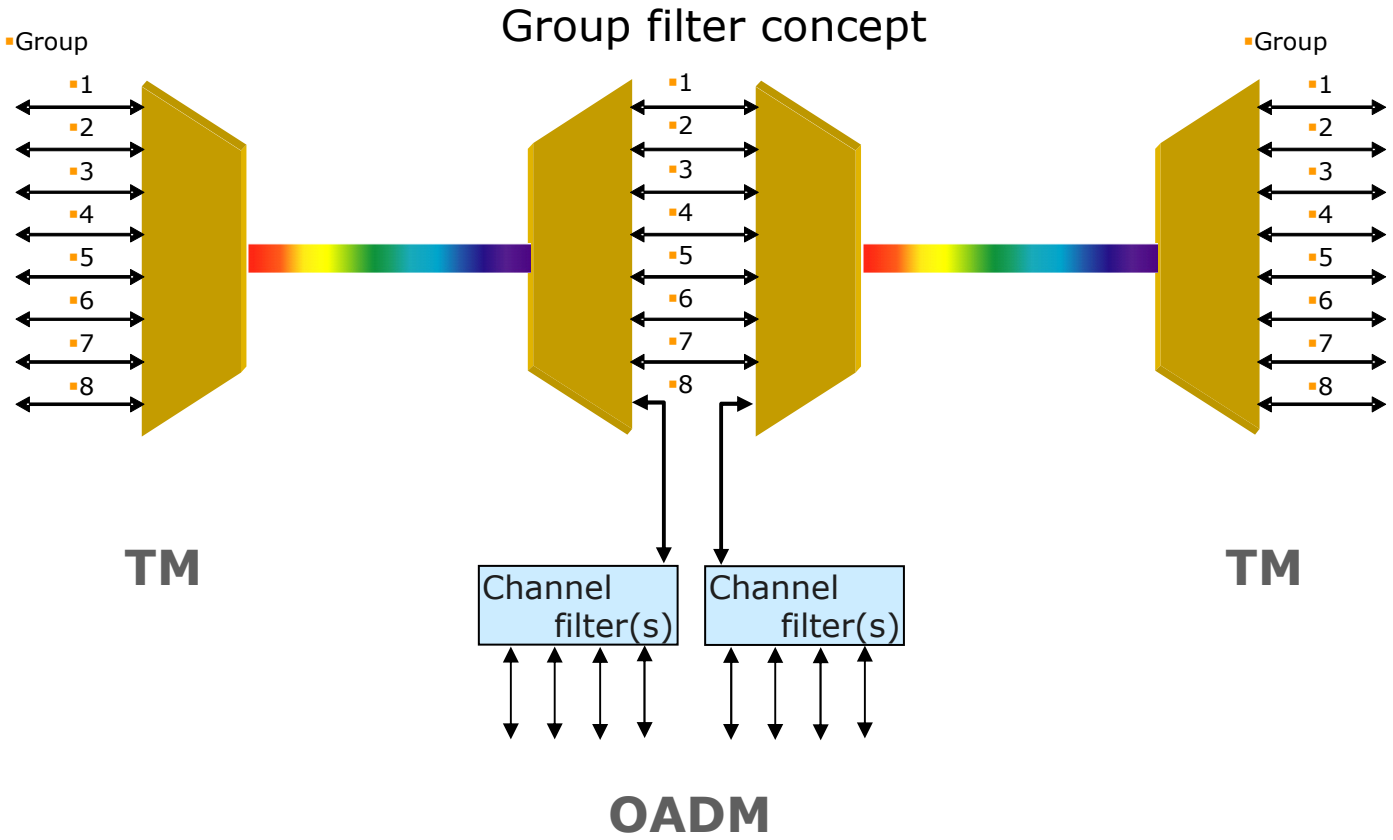
DWDM systems, Terminal (OTM)



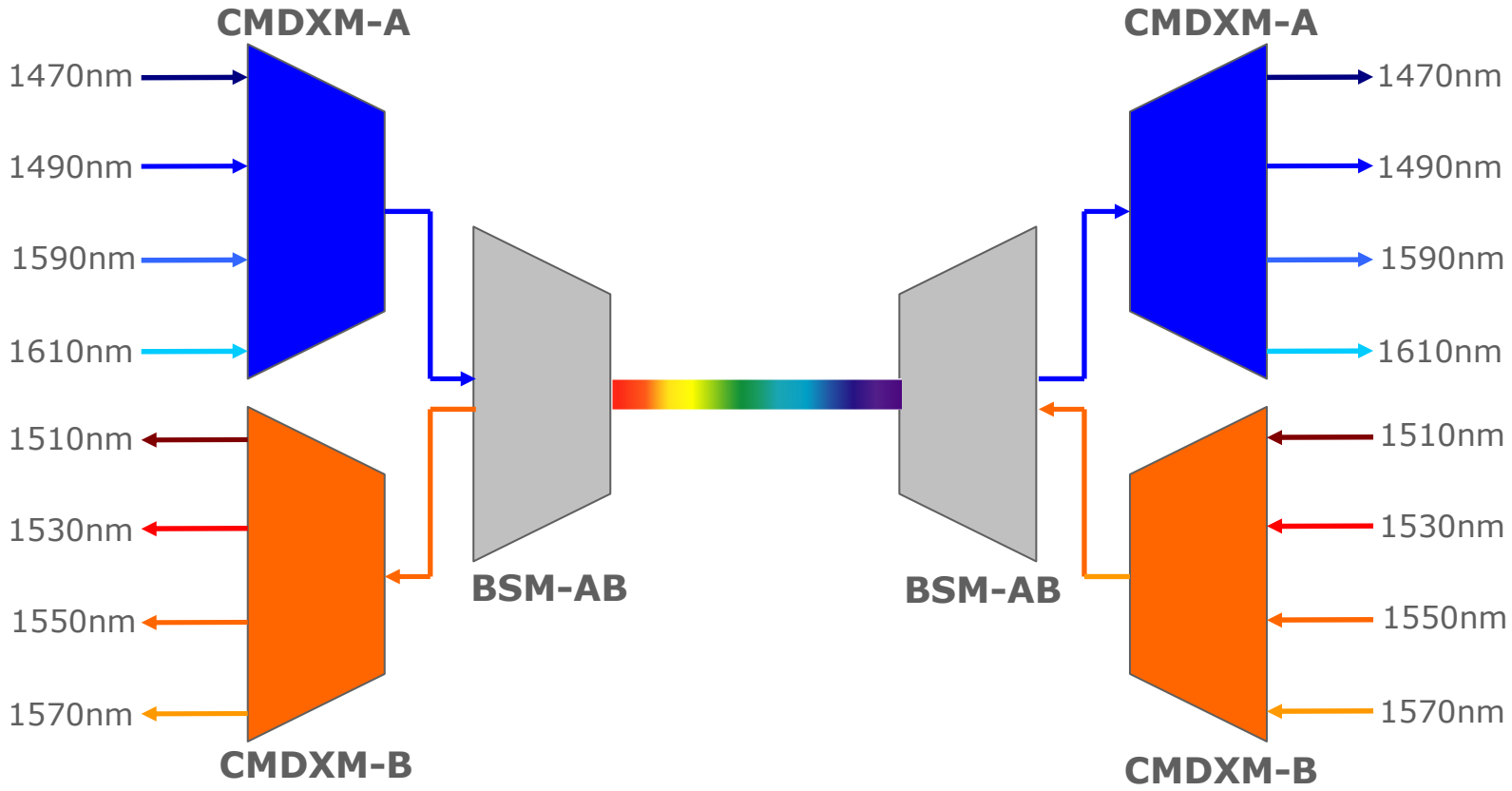
DWDM systems, In Line Amp (ILA)



DWDM systems, Optical ADM (OADM)



CWDM SFW
8λ 4Channel Filter Architecture



SFW pros and Cons

Pro

- Less disturbance in maintence
- WDM SFW can reduce fibre cost

Con

- Filter cost higher at certain points
- Not easy to amplify
- Less intuitive
- Less easy to combine CWDM/DWDM-scalability issue
- Not compatible with 1310 passtru
- Typical is Telecom operator=Dual fibre
- Storage application/enterprise-DFW or SFW

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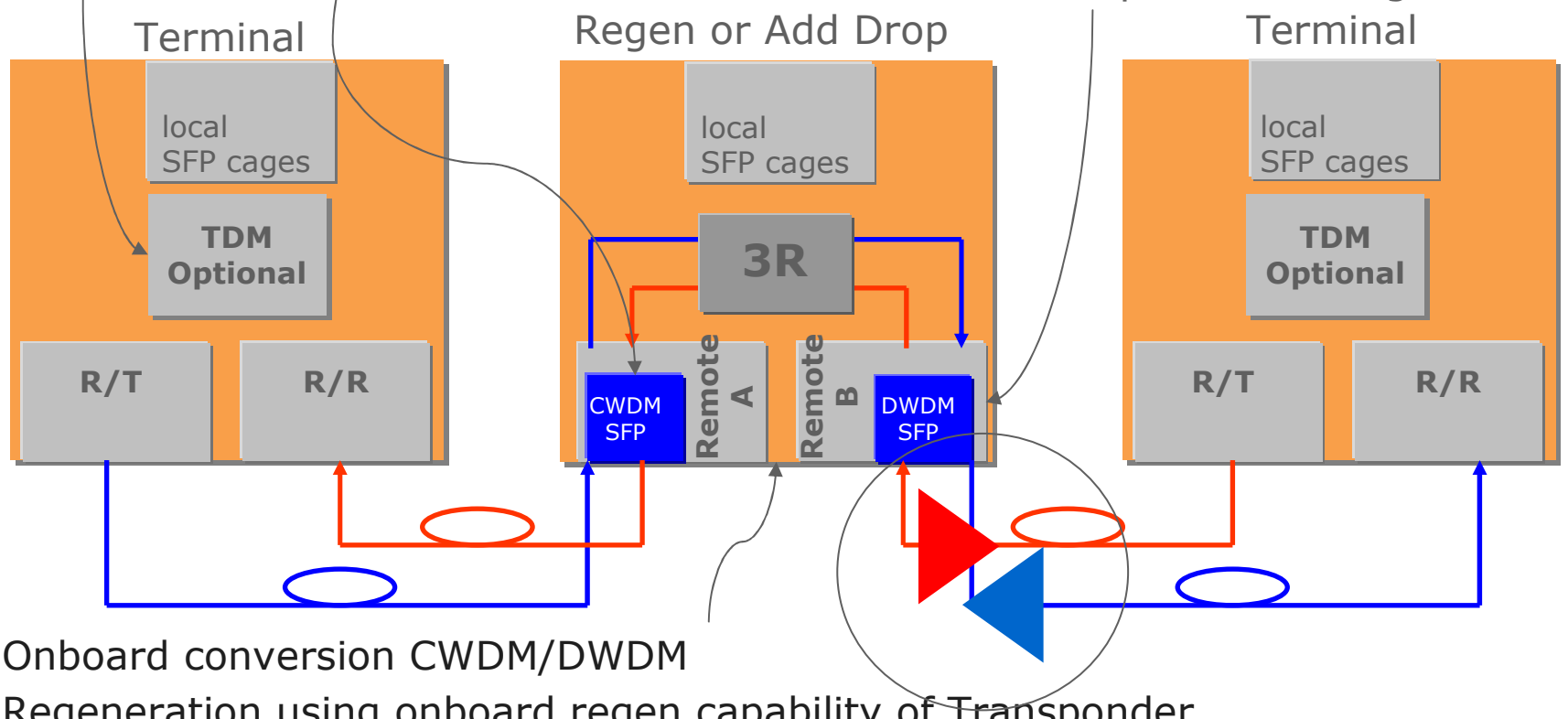
Example-
Best value for money approach

- Multiplexing of lower bitrate using TDM
- CWDM for lowest cost on shorter spans
- DWDM and Amplifiers on longest



- Onboard conversion CWDM/DWDM
- Regeneration using onboard regen capability of Transponder

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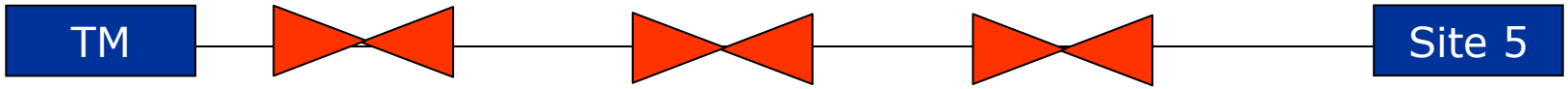
Amp solution vs regenerator based



The classic amplified DWDM system
You pay a high initial price- but new capacity is only adding TRXs

- But what if I turn the amps into ”industrialized” Regens?

The Infinera regen model

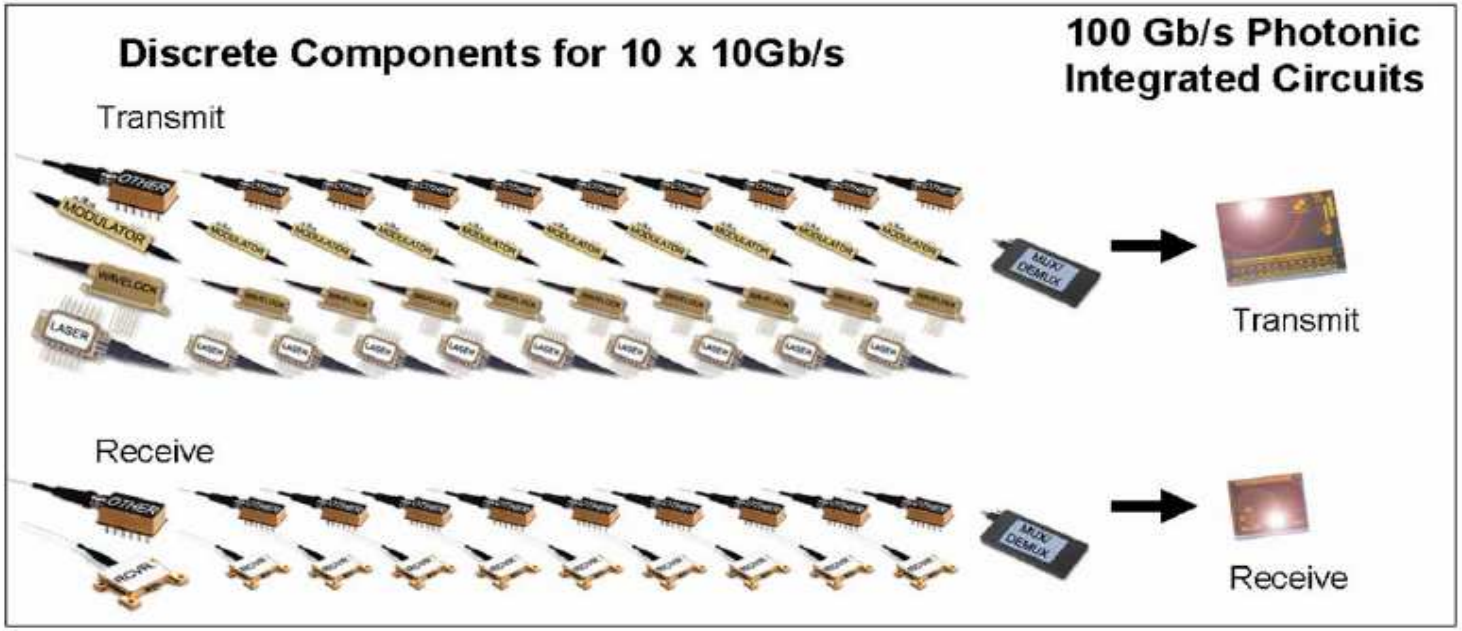


Figure 1: Large-scale Photonic Integrated Circuits enable monolithic integration of over 60 discrete optical components.

This is the good argument Infinera shows off

But what they dont say-

You have to buy 10* 10G channel at time

ou have to install regens for every channel upgrade- this doesnt happen in the classic model

Is it costeffective? No one knows as Infinera is not a public company

Is it worth following up? Yes..

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The future (?)

- **Reconfigurability**
  - Are HW price points met?
  - Are more dynamic networks required (1G and up)?
- **More functionality**
  - GMPLS something useful??
  - L2/3 functionality
  - More TDM functionality
  - G709 fully implemented
- **40Gbit, 100Gbit, 160 Gbit…**
  - Future components?
  - Regeneration (arrayed regen chips) or amplification (PMD compensation etc.)

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