Good Things Come in Small Cubes

TERENA NGN Workshop:
Deploying CWDM & DWDM in Research and Education Networks

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Cube Optics AG

Cube Optics: Access Solution Provider

- Headquartered in Mainz (GER) – Presence in US, CA, IL, ES, FR, SE, NL, NR, IT, UK, JP, SL, AT, MX, PR, PT,…
- Only EU fiber-optical component & WDM system manufacturer
- Access Solutions for OEMs and Network Operators

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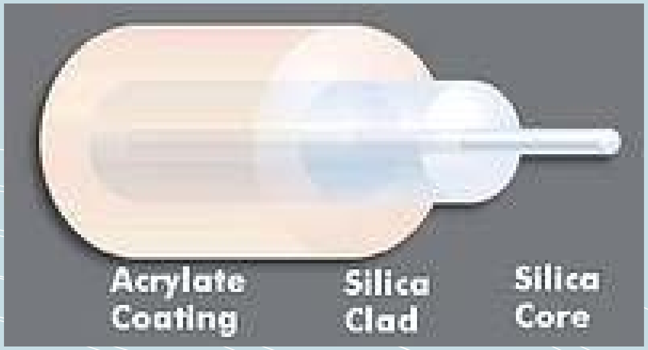
Content: Deploying CWDM & DWDM in REN

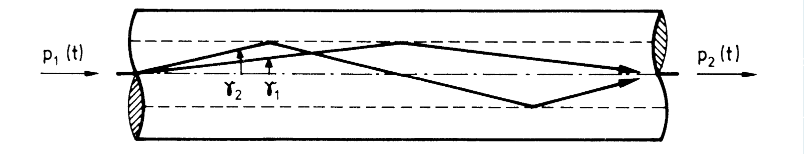
- Optical transport basics (single / multi mode fibers, insertion loss, dispersion)
- Wavelength Division Multiplexing:
  - Set-up / Function
  - DWDM, CWDM, WWDM and how this relates to applications and matching transceivers
- Passive WDM Networks
  - Active vs. Passive WDM Systems
  - Principal architectures

Structure of an optical Fiber

- **From the center outwards:**
  - Fiber core (glass), diameter 9 ... 62,5µm
  - Gladding (glass, lower refractive index than the core), diameter 125µm
  - Coating (acrylate), diameter 250µm
  - Jacket (loose tube or tight buffer), diameter 900µm
  - Outer jacket (diameter typically 2-3mm)



- **Transport of light in the core by total reflection at gladding**



Fiber types

Multi Mode Fibers:

- Core diameter: 50µm (EU) / 62.5µm (US)
- Advantages: Lowest cost transceivers, simple connections
- Disadvantages: Short reach (ca. 500m) due to bandwidth-length-product
- Applications: LAN, Equipment interconnection

Single Mode Fiber:

- Fiber core: Diameter 8,2µm
- Standard fiber: SMF-28 (Manufacturer: Corning)
- ITU Standard: G.652 (A, B, C, D) – Impact on Dispersion
- Application: From LAN to WAN

Specialty Fibers:

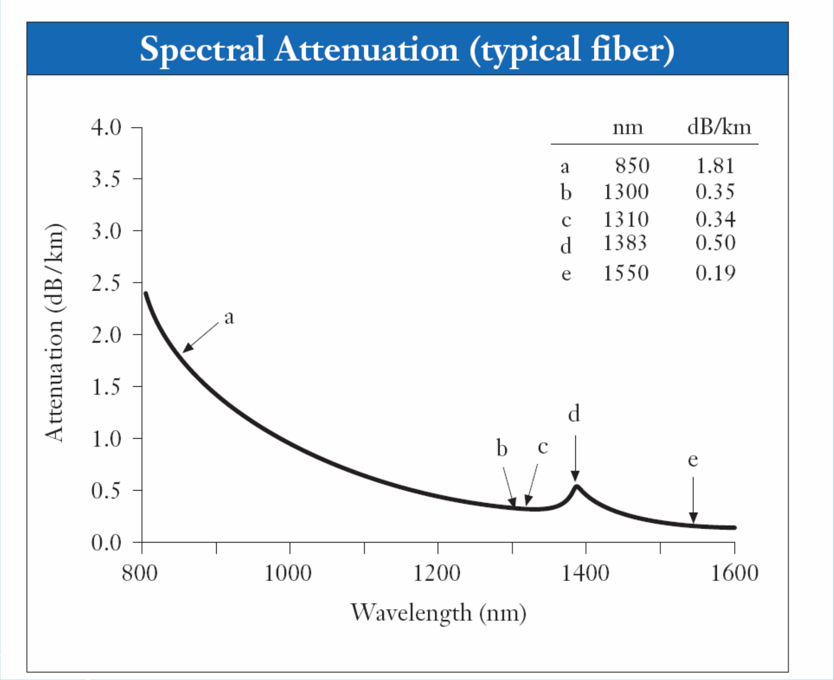
- E.g.dispersion shifted fiber (Dispersion min. @1550nm instead 1310nm)

Transport Limiting Factor: Insertion loss

- Fiber Loss: dependent on length, lambda and fiber type (e.g. Corning SMF-28)

  (typ. 0.25dB/km @ 1550nm

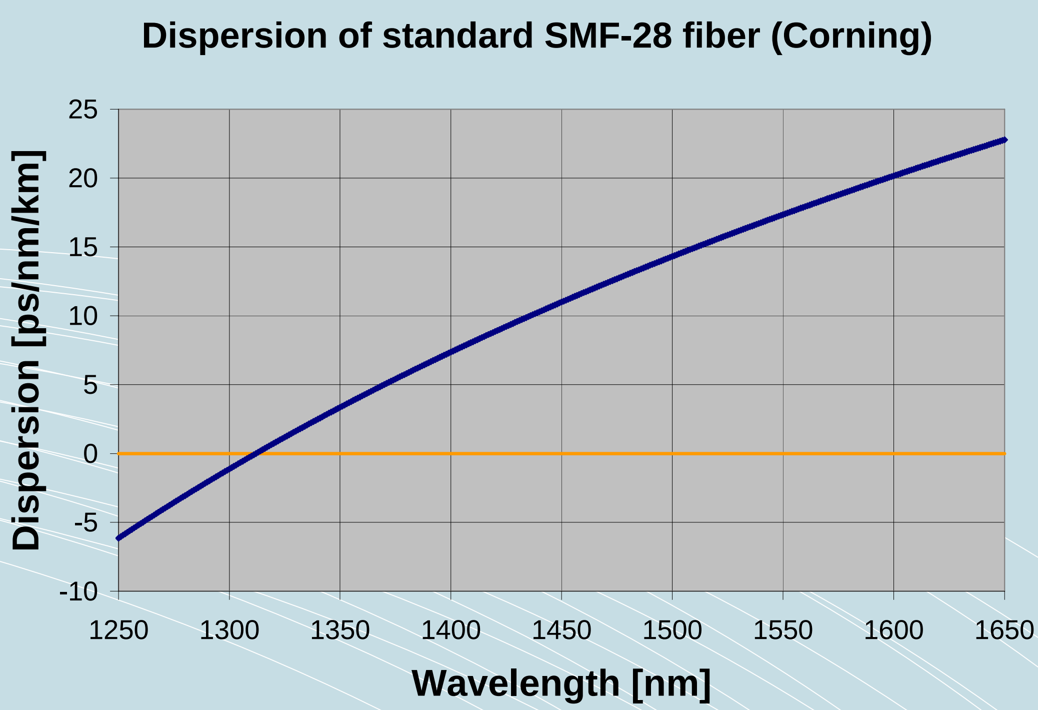
  0.35dB/km @ 1310nm)



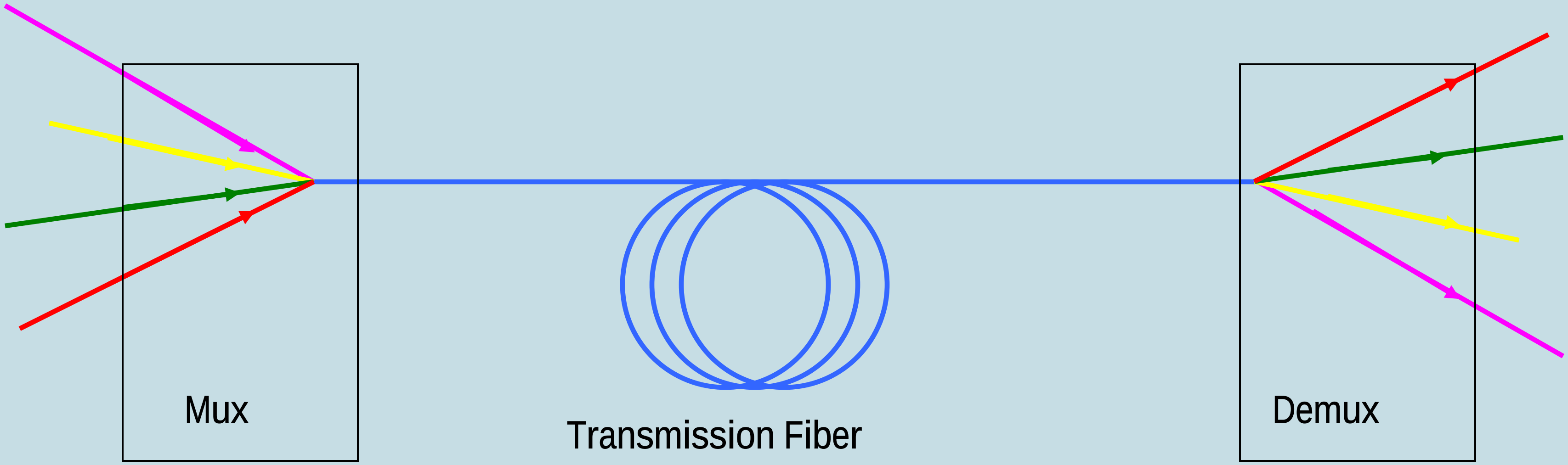
- Passive optical component loss (multiplexers, couplers, ...): component specific.
- Optical connectors also introduce loss (dust is #1 on troubleshooting)
- **Thumb rule: Transport up to 2.5G is loss limited, 10G+ is dispersion limited**

Transport Limiting Factor: Fiber Dispersion

- **Chromatic Dispersion**: signals of different wavelengths propagate at different speed
- Laser line width is finite, so the dispersion lowers signal quality
- The dispersion therefore limits the transmission distance
- Impact of dispersion depends on data rate (no role at Gig E, important at 10Gig E)

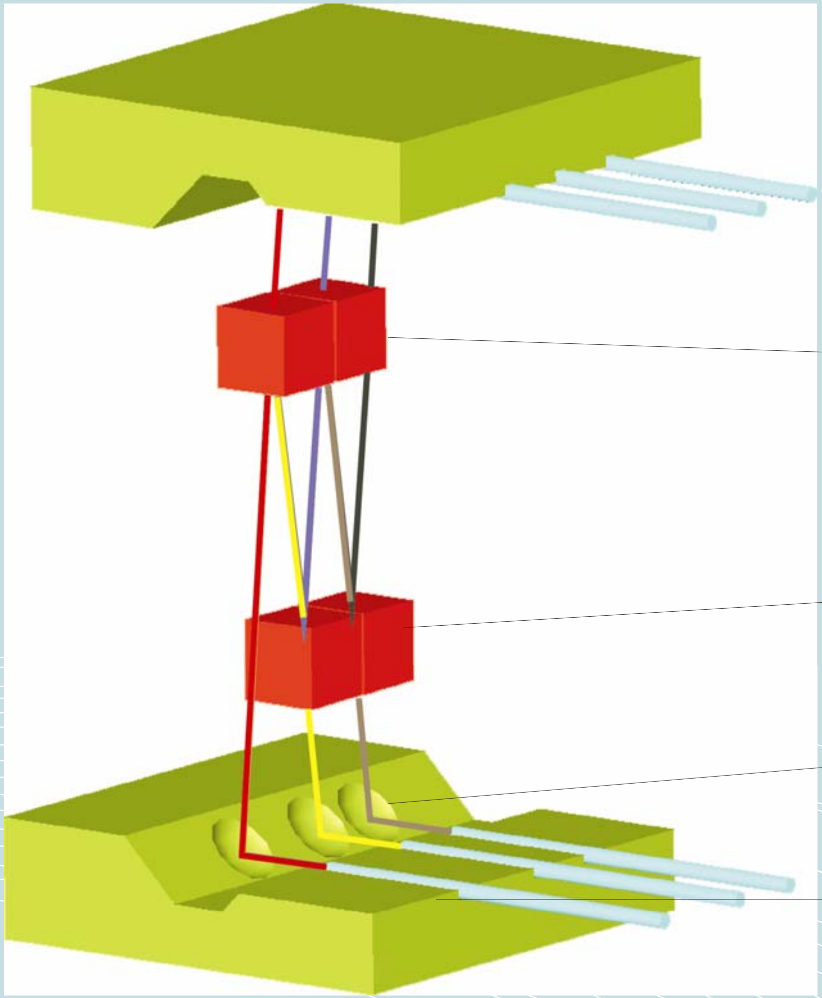


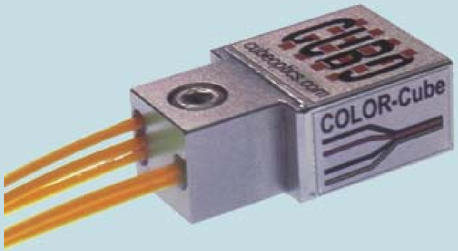
Optical Multiplexing: Principal



- **Fused couplers** can be used to mux => 50% loss per combination!
- λ-sensitive fused couplers (**WDM Couplers**) can be used as well as Demux => Very low Isolation => Cross Talk => High Bit Error Rate
- Combining (Mux) and Separation (Demux) of several channels / wavelengths via interference filters (**TFF technology** for C/DWDM)
- Constructive / destructive interferences enable, “loss-free” muxing and demuxing

CUBO’s Mux Set-up





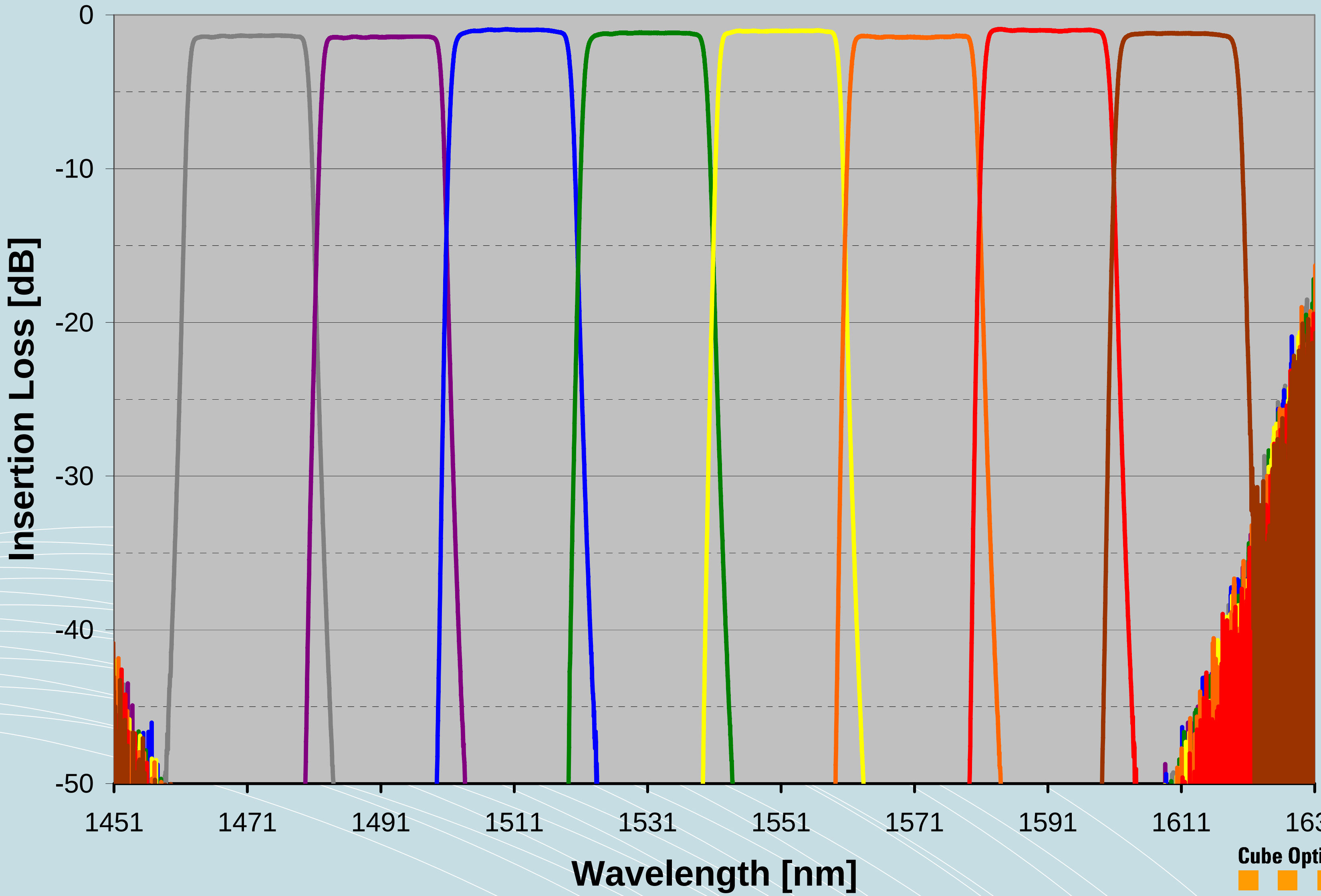
Each TFF transmits 1 channel and reflects the rest (Isolation)

Cascaded TFF filters. Beam directions are reversible (bi-di use).

Beam shaping

Passive fiber alignment

Example Spectrum: 8 ch. CWDM (1470-1610nm)



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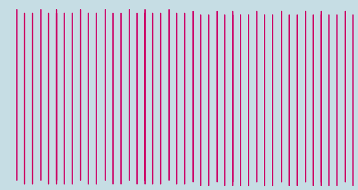
Channel Grid and Muxes

Special Bandfilters: EXP, Upgrade, etc.

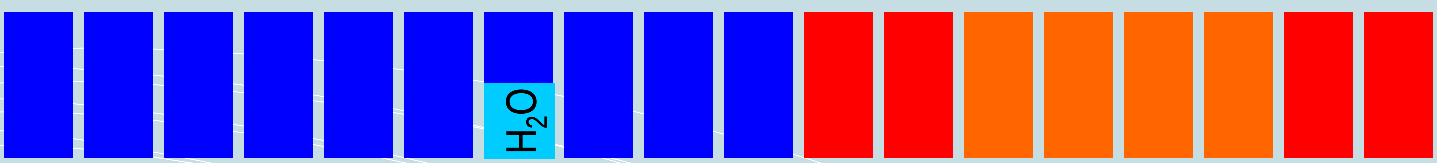
CWDM „blue“ upgrade

EXP: „gey“
1550nm SFPs

DWDM (Dense Wavelength Division Multiplex):
>100 channels / 200GHz, 100GHz, 50GHz grids /
Spacing 1.6nm, 0.8nm, 0.4nm



CWDM (Coarse Wavelength Division Multiplex): 18 channels
(1271, 1291, …, 1611nm / Spacing: 20nm / Channel width: 13nm



WWDM (Wide Wavelength Division Multiplex): 2 channels

1310nm (1260-1360nm)

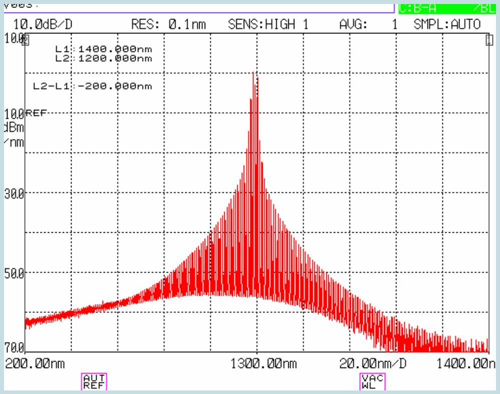
1550nm (1460-1620nm)

1270 1290 1310 1330 1350 1370 1390 1410 1430 1450 1470 1490 1510 1530 1550 1570 1590 1610

Transceivers: “Grey vs Colored”

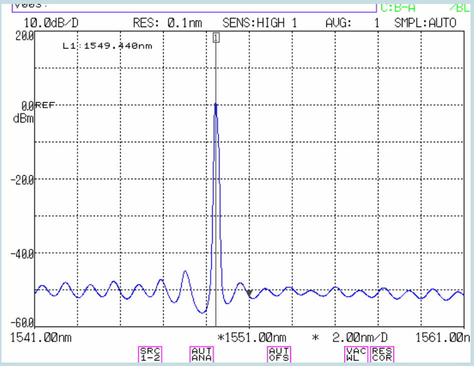
„Grey“ Transceivers:

- VCSEL lasers (850nm, MM),
  Fabry Perot lasers (1310nm / 1550nm)
  (DFB laser for >10G &/ WAN)
- Easy and simple to manufacture => Very low-cost



„Colored“ Transeivers:

- Only DFB lasers (<1nm width)
- DWDM = temp. stabilized CWDM



General:

- ALL detectors work over the complete spectrum, only the lasers are different colored (=> option for multiple-l **bi-di transmission**)
- Only DWDM may be amplified, if C or DWDM is best depends on many factors (reach, channel count, data rate, protocol...)

How far do I get?

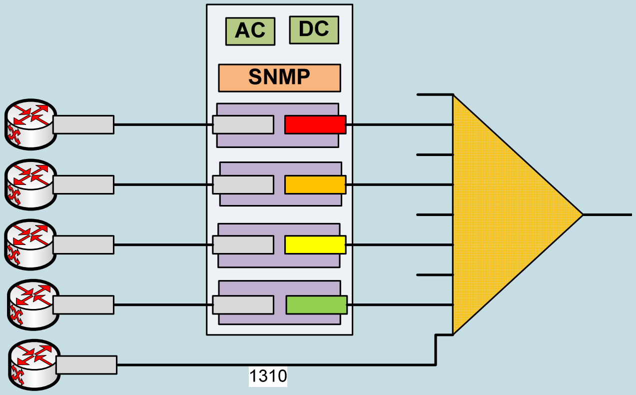
- Reach is limited by loss /& dispersion
- **Reach specifications** refer to best conditions without additional losses (splices, connectors, muxes) and optimum dispersion characteristics (so reach is only a hint)
- Different reach results from different **power budgets**. These are achieved by combining higher / less sensitive detectors (PIN vs. APD) with different laser diods
- Power Buget = Min Tx – Min Rx
- The reach is then given by:

Link Loss = Sum of ALL Losses + 3dB < Transceiver Power Budget

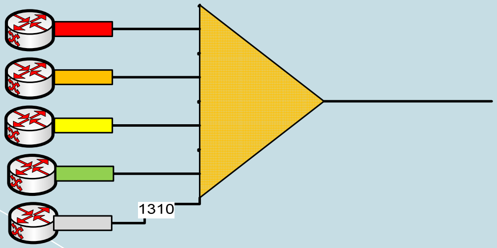
- **Dispersion** leads to a loss penalty, reducing the effective power budget of the transceiver

Active Vs Passive Transport

- **Active Transport System:**
  - Conversion from client ("grey") to line (colored) signals by transponder cards
  - Since being "active" a chassis with red. power and management (SNMP) is needed
  - Flexible but complex

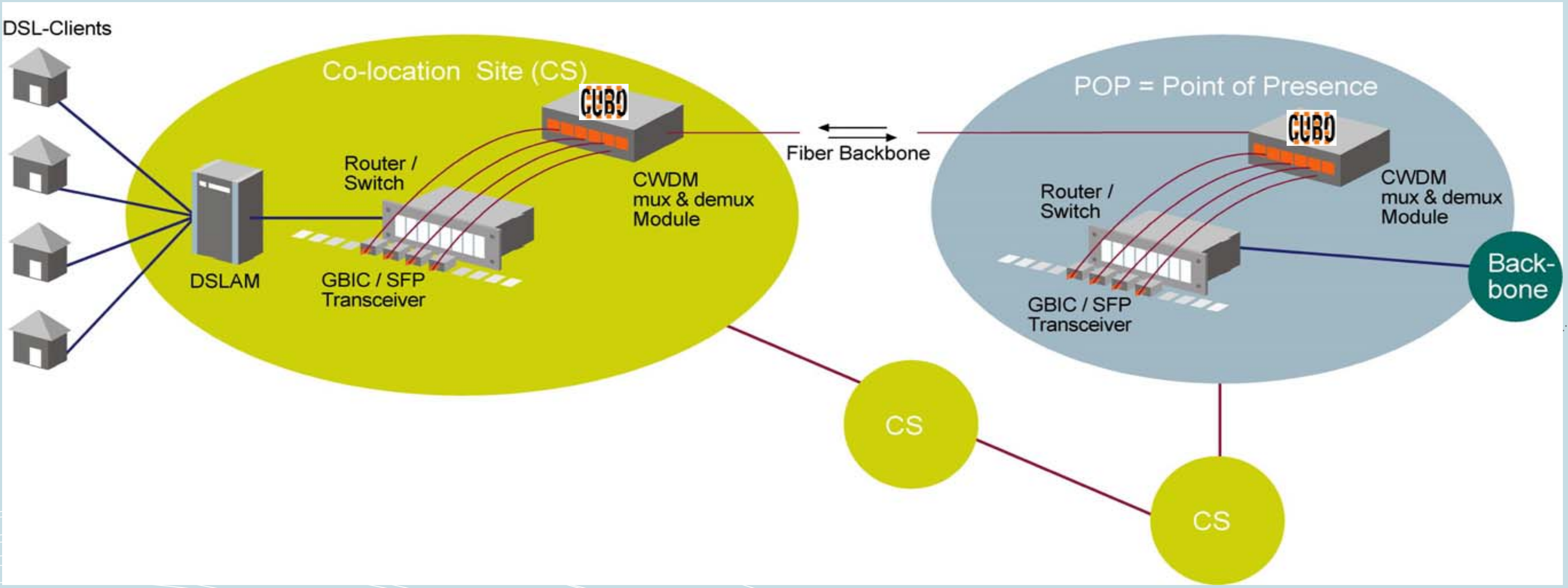


- **Passive WDM System:**
  - No conversion, transport transceivers are plugged straight into terminal equipment
  - Less active elements => higher reliability
  - Transceivers are managed by terminal equipment (Switch, DSLAM, etc.)



Application: Dark Fiber Access Networks

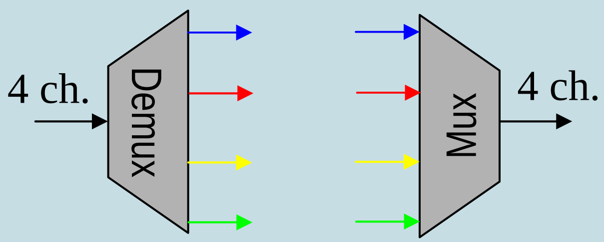
Optimizing Dark Fiber Lease by multiple use through passive Muxes



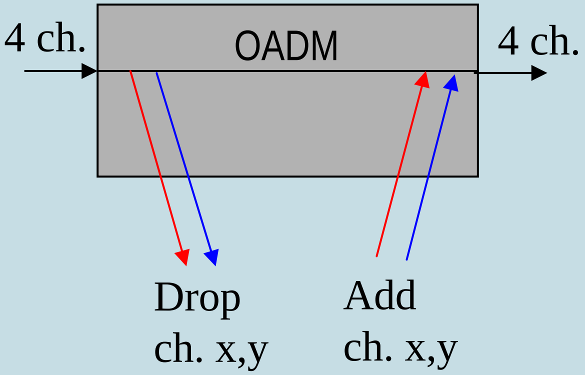
2 Principal Designs: MUX vs OADM

- Two different multiplexer types:

Mux&Demux



Add&Drop (OADM)



All channels are terminated,

No channel passed through transparent)

Some channels terminated,

Rest passed through (optical

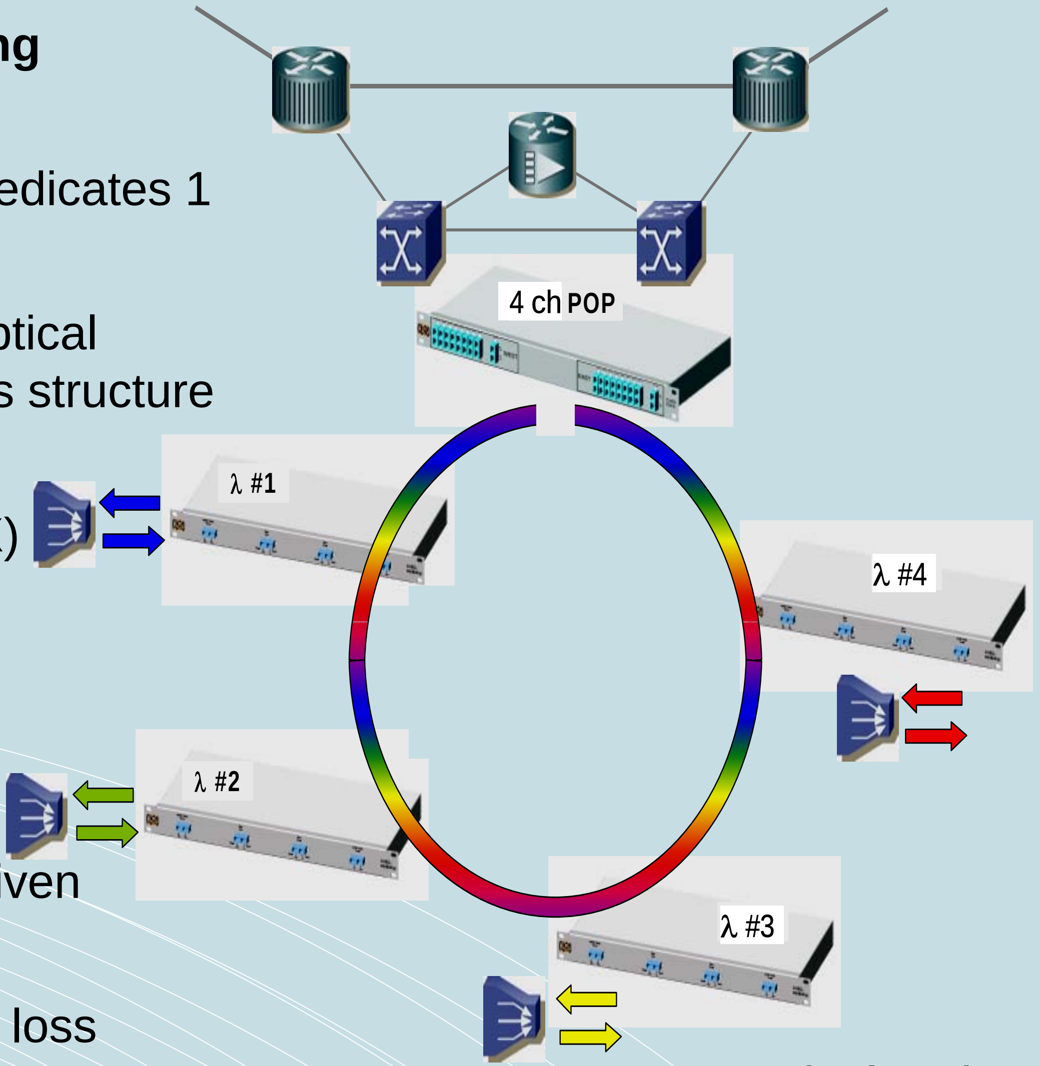
- …enable two network architecture variants:

  Sharing / Dedicating Traffic in Rings, see next slides

Dedicating Channels: OADM based Rings

Example 4 nodes in redundant ring architecture

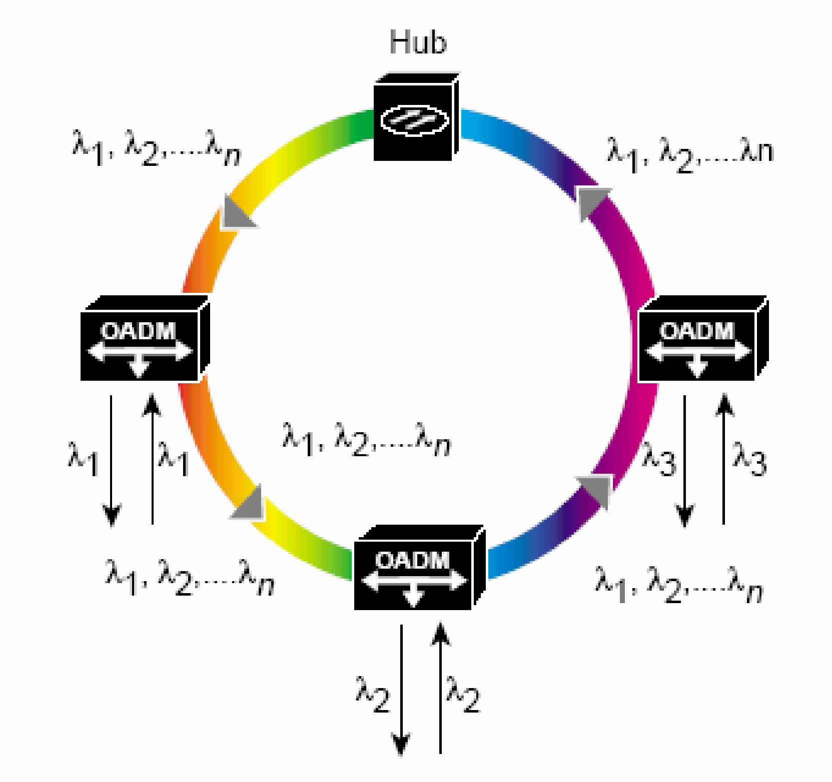
- Specific OADM for each node dedicates 1 channel to each node
- No need for L2/L3 switching, “optical routing” with direct hubs&spokes structure on L2
- Low qty of transceivers (CAPEX)



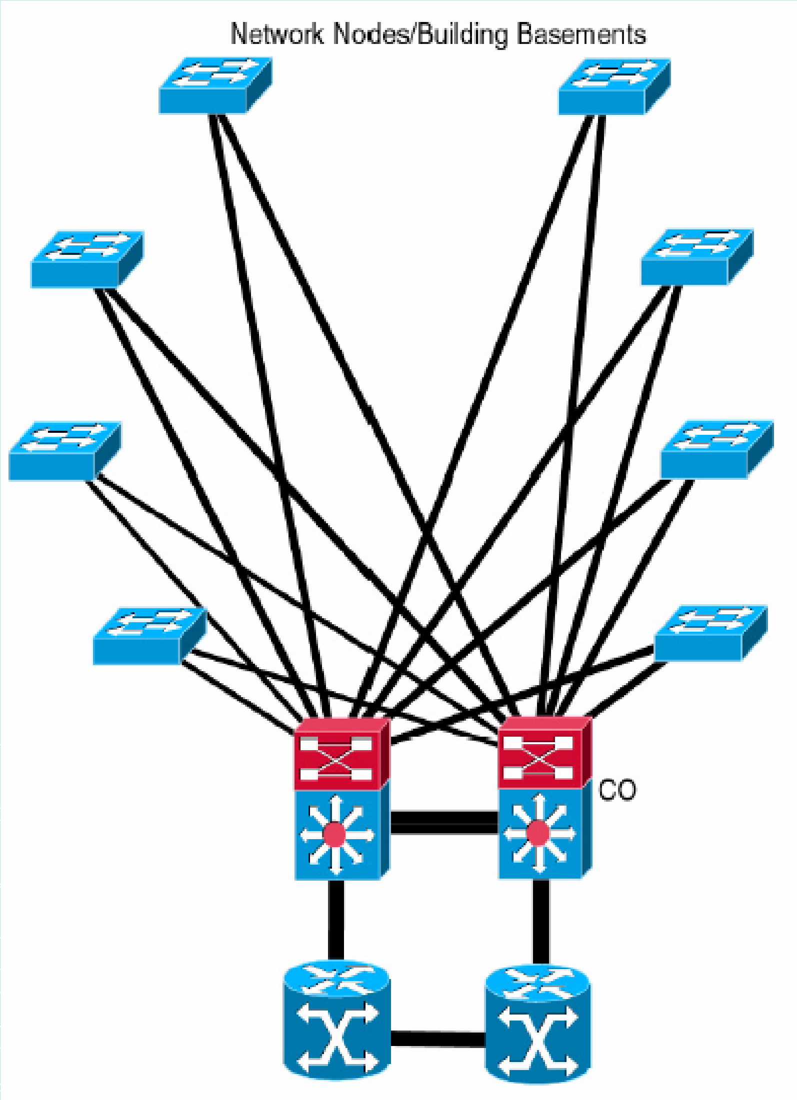
- Higher variety of mux parts
- Less flexible than Mux&Demux
- Number of nodes depends on given channels
- Challenging for large rings (Link loss limited)

Dedicating Channels: OADM based Rings

Layer 1: Optical Layer view



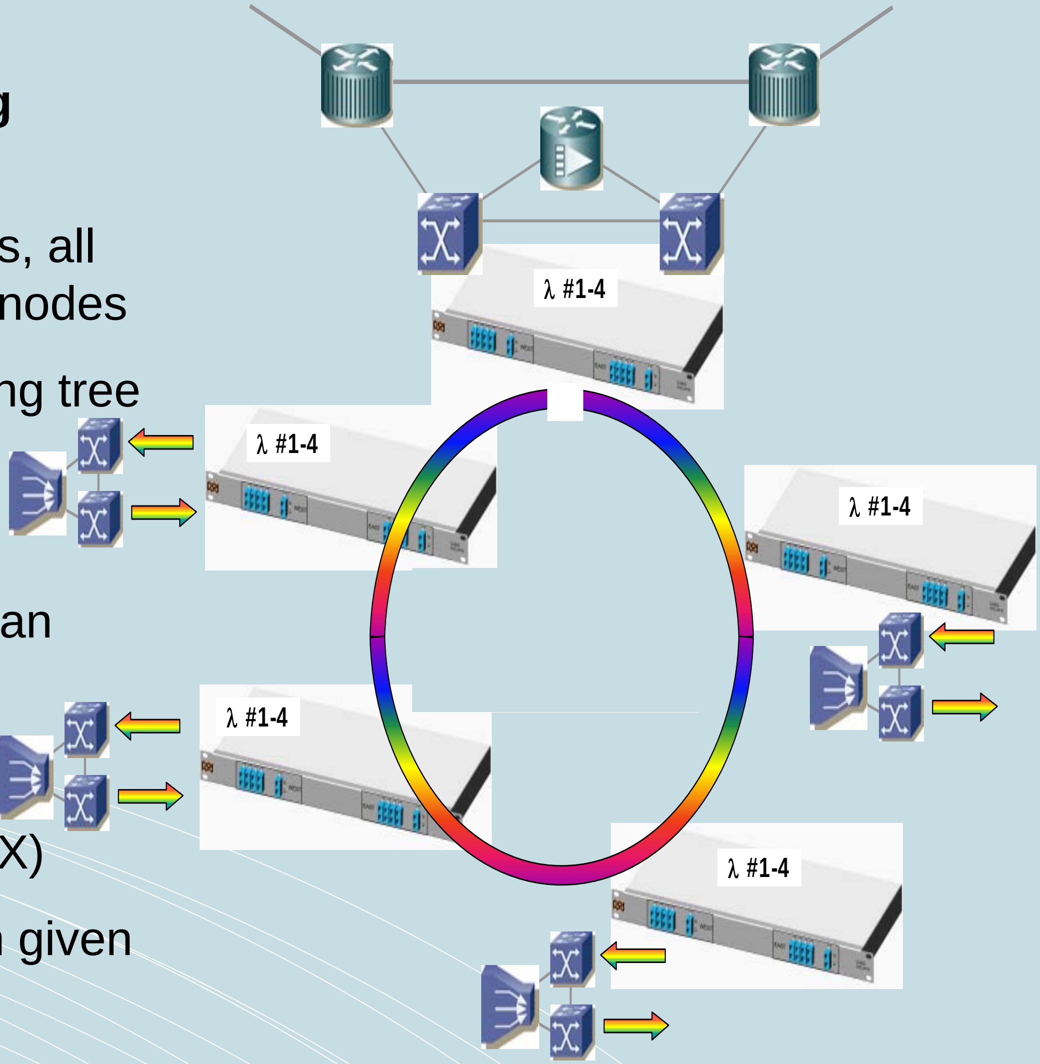
Layer 2: Ethernet view



Sharing traffic: Mux&Demux based Rings

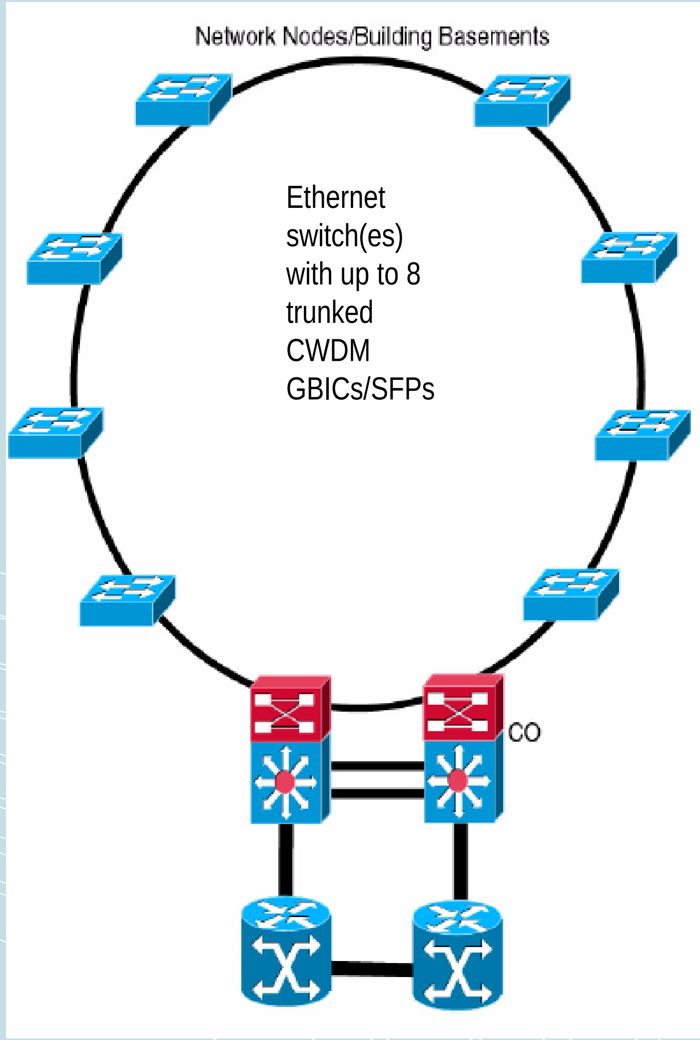
Example 4 nodes in redundant ring architecture

- Same Mux&Demux in all locations, all channels are shared between all nodes
- Need for L2/L3 switching (spanning tree protocol)
- Higher flexibility than OADM
- Easier design and provisioning than OADM designs, not loss limited
- Higher qty of transceivers (CAPEX)
- Number of nodes independent on given channels



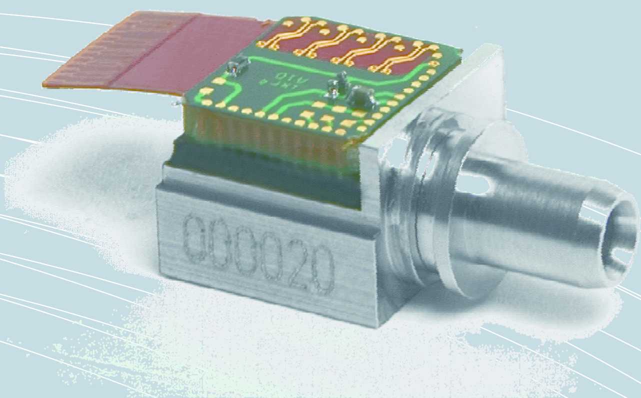
Sharing traffic: Mux&Demux based Rings

Layer 2: Ethernet view



Outlook 100 G

- Higher data rates most likely only be achieved by multi-λ transceivers
- **ITU HSSG** is analysing options and will make standard suggestions
- In discussion today: 4 x 25G versus 10x 10G
- Both as CWDM or DWDM
- Standards expected for 2010, pre-standard products for 2009



CUBO's multi-λ ROSA

Thank you!

We look forward to provide you with further information.

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