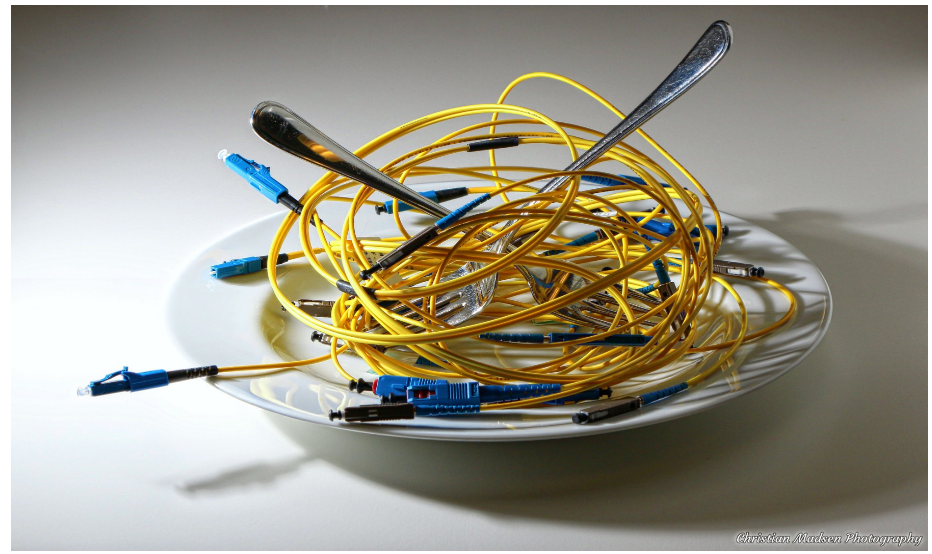
Kitchen table DWDM

Kein
feinsmeckerei



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DeIC/sep. 2014

(Working with optical parameters for simple DWDM systems)

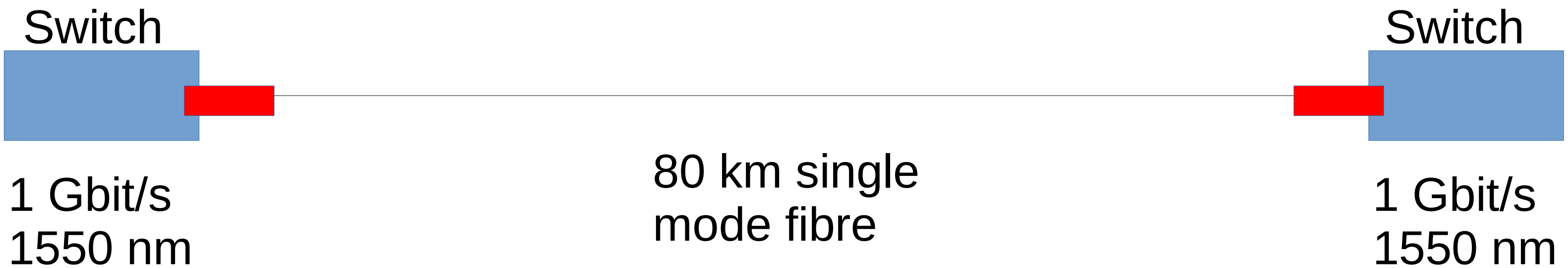
Tools and prices

Each channel:

- Using LAN optics 2 x € 1.000
- Using PandaCom transponder 2 x € 4.000
- Using Alcatel 1626 transponder 2 x € 10.000

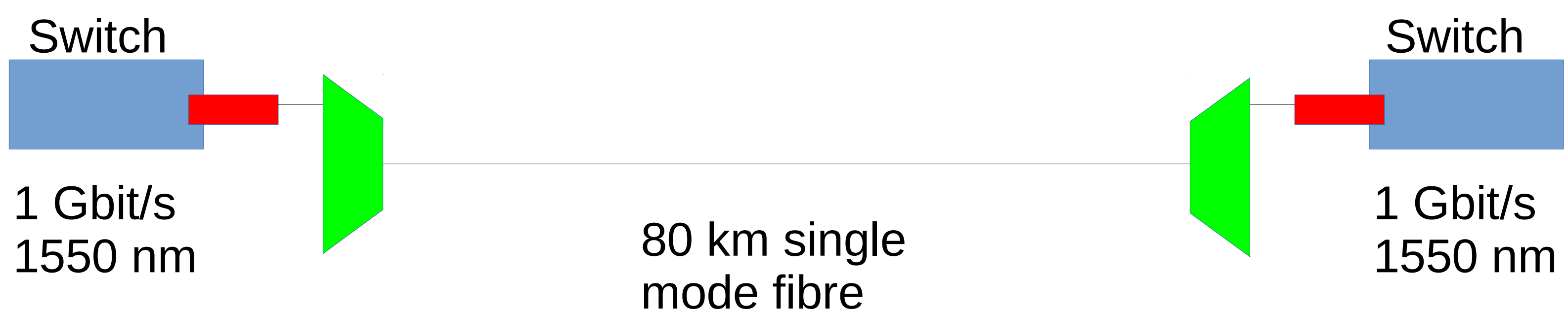
But only Alcatel/Cienna makes promises

1 Gbit/s transmission using LAN optics



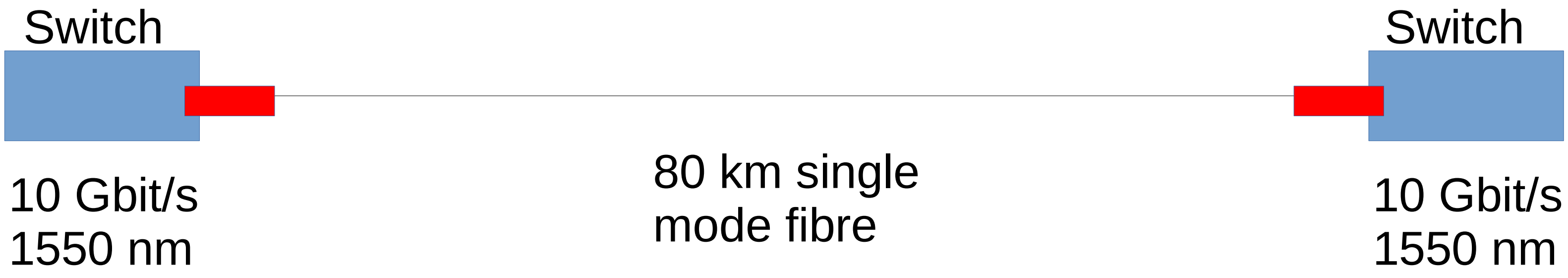
80 km ZX optics - succes

1 Gbit/s using CWDM optics



Doesn't work – why not?
80 km is not 80 km! 80 km is 27 dB powerbudget!
8 ch. CWDM Mux/Demux costs 4 dB

10 Gbit/s transmission



Doesn't work – why not?

Chromatic dispersion may be the answer.

Chromatic dispersion

Do read:

http://www.imedea.uib.es/~salvador/coms_optiques/addicional/ibm/ewtoc.html

Chromatic dispersion misshapes the pulse signal.

It can be measured – but the typical value is fine

Dispersion Compensating Modules are sold as ”n km” - don't waste time/money on measuring

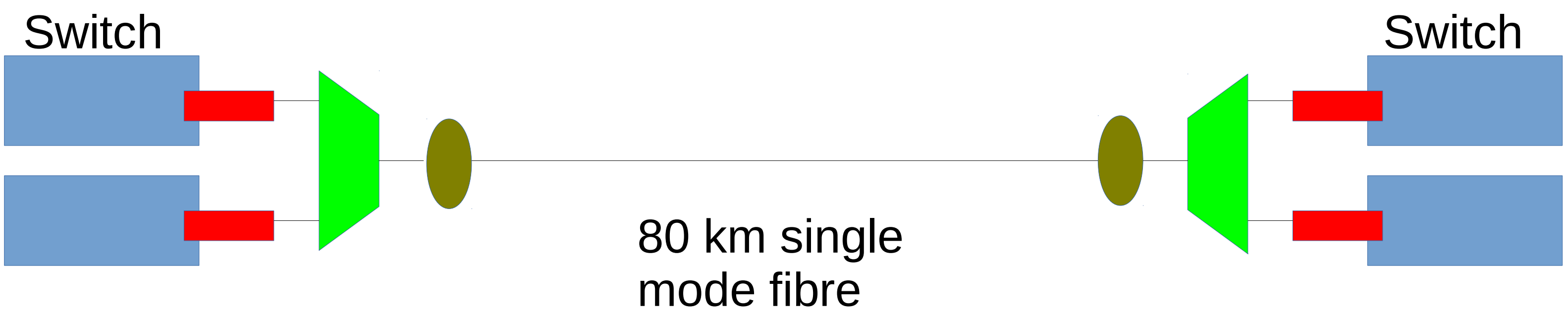
Chromatic dispersion

- Dispersion becomes a problem for a receiver when it exceeds about 20% of the pulse length
  - a 1 Gbit/s pulse fills 1 ns
  - a 10 Gbit/s pulse fills 100 ps
- Dispersion = 17ps/nm/km × spectral width × length of fibre
- Modulation broadens the signal by twice the highest frequency present in the modulating signal
- A narrow spectral width laser might produce only one line with a linewidth of 300 MHz. Modulating it at 1 Gbps will add 2 GHz. 2,300 MHz is just less than .02 nm (at 1500 nm).

Chromatic dispersion

- Calculating chromatic dispersion for 80 km fibre you get: 17 ps/nm/km * 80 km = 1360 ps/nm
- Hence dispersion is 1360 ps/nm * 0,02 nm = 27,2 ps
  - well below 20% of 1000 ps
- At 10 Gbit/s dispersion will be 272 ps – almost three times the pulse size.

Power



8 channel MUX/DEMUX ≈ 2 dB each end
40 channel MUX/DEMUX ≈ 5 dB each end

Power calculation (8 channel)

MUX	2 dB
80 km fibre	27 dB
DCM	2 dB
DEMUX	2 dB
Total cost	33 dB

Max Power budget for 10 G SFPs is 27 dB

We need an amplifier!

Power

Tracing the power – each channel:

Sending	Cost	Output level
Switch		+1 dB
MUX	2 dB	- 1 dB
80 km fibre	27 dB	-28 dB
AMP	+10 dB	-18 dB
DCM	2 dB	-20 dB
DEMUX	2 dB	-22 dB

Here a preamp is used (low input level, low noise)

Booster amp is another option

Power

The total power must be considered too

- 1 channel feeds +1 dB into the fibre
- 2 channels feeds +4 dB into the fibre
- 4 channels feeds +7 dB into the fibre
- 8 channels feeds +10 dB into the fibre
- 16 channels feeds +13 dB into the fibre
- 32 channels feeds +16 dB into the fibre

adding a booster (e.g. + 17 dB) will cause non-linear effects!

Some testing

To verify the mentioned effects a test setup was created.

A transmission tester was used to do BERT testing on a 80 km single mode fibre.

The BERT was set to measure unframed layer 1 for 10 minutes

Some testing

- Warmup: 1 Gbit/s, 1550 nm, 70 km/21 dB optic

  Received -20 dB – 0 errors

- 10 Gbit/s, Ch 39, 80 km optic

  Received -20 dB – 50 Mio errors, BER 8 10^{-6}

- 10 Gbit/s, Ch 39, 80 km optic + 60 km DCM

  Received -22,3 dB – 1000 errors, BER 2 10^{-10}

- 10 Gbit/s, ... + 60 km DCM + 40 ch. MUX/DEMUX

  Received -31,5 dB – NO TRANSPORT

Some testing

- 10 Gbit/s, … + DCM + Mux/Demux + 20 dB AMP

  Received -12,3 dB – 0 errors
- Testing DWDM - Adding a ch 41 'noise' at +1 dB

  Received -12,8 dB – 0 errors
- Testing Linearity (same setup, but Ch 39 is dampened)

0 dB	Received -12.9 dB	- 0 errors
5 dB	Received -18.2 dB	- BER $3\ 10^{-12}$
10 dB	Received -22.0 dB	- BER $1.5\ 10^{-5}$

My conclusion

- Don't be afraid of kitchen table DWDM
- Be aware!

- Make sure dispersion is properly compensated
- Make sure signal levels are fairly balanced
- When using amplifiers direction matters
- To keep control over power levels, transponders may be worth the cost – transponders can do FEC as well