SWITCH

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- DWDMlight -

lightweight optical links from mixed-vendor equipment

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Outline

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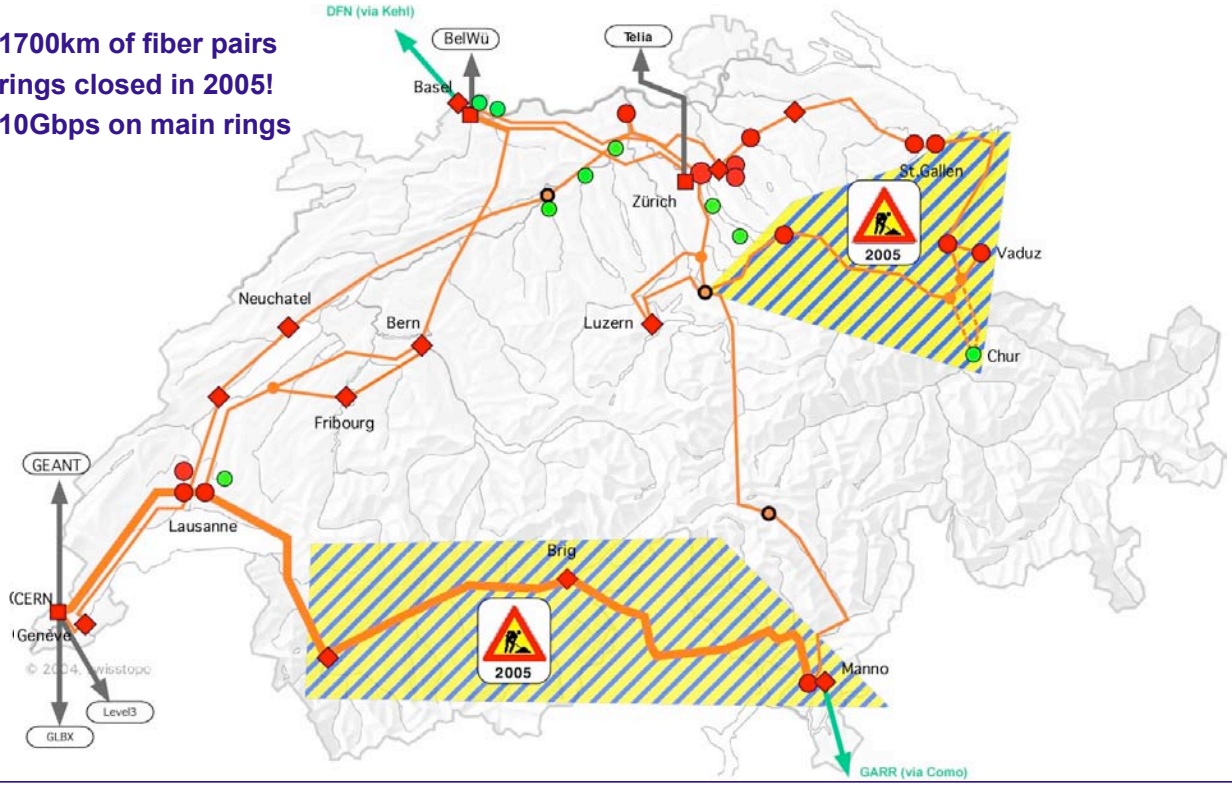
- DWDMlight - what & why
- Design
- Roll-out
- About CEF strategies
- The last words

SWITCHlambda dark fiber topology

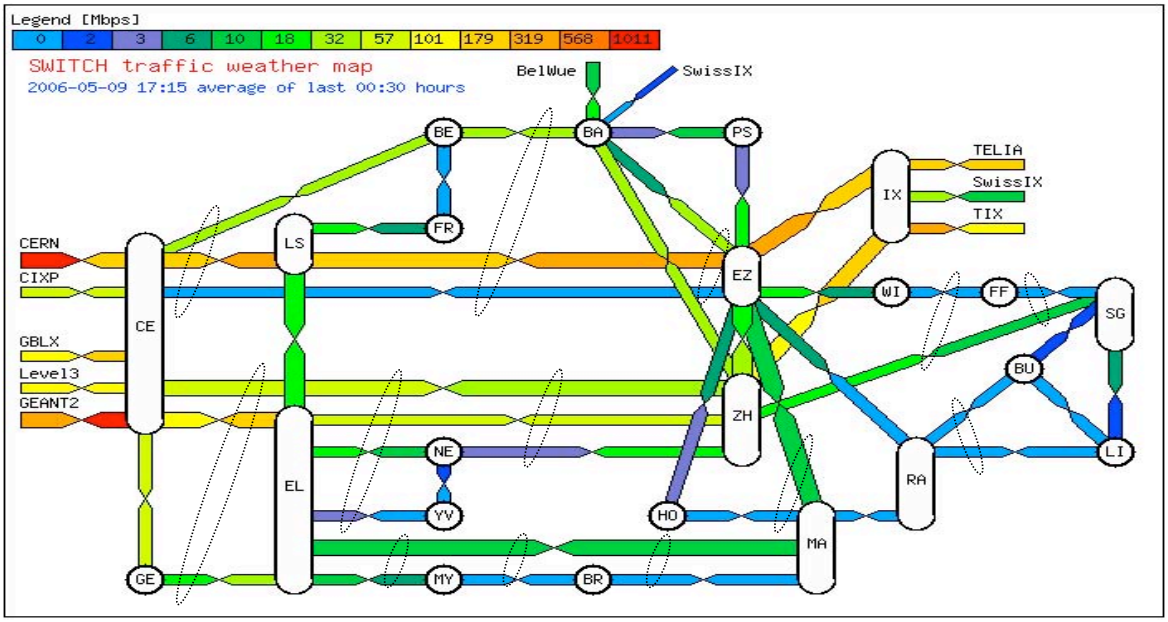
- 1700km of fiber pairs
- rings closed in 2005!
- 10Gbps on main rings



SWITCHlan basics

- SWITCHlan is mostly an IP network
- SWITCHlan is built in single fiber, bi-directional technology
  - allows to run at the same time on one pair of fibers
    - a nation-wide DWDM backbone network
    - short range point-to-point Gigabit Ethernet links
  - might limit our options at the next technology upgrade (but does not have to)
- we use DWDM to realize at the same time
  - direct IP links between network hot spots (Geneva, Zurich, Lausanne...)
  - IP links between adjacent university sites
  - direct optical paths between any sites
- we use CWDM with plug-in optics to realize
  - point-to-point (bi-directional) Gigabit Ethernet links
    - distances up to ~100km
    - standard wavelengths 1530nm + 1550nm
  - lambda-tunnels
    - SWITCH provides spectrum, client operates active equipment
    - endpoints not restricted to SWITCH PoPs - passive add/drop filters can be placed at selected points along existing links (e.g. railway stations)

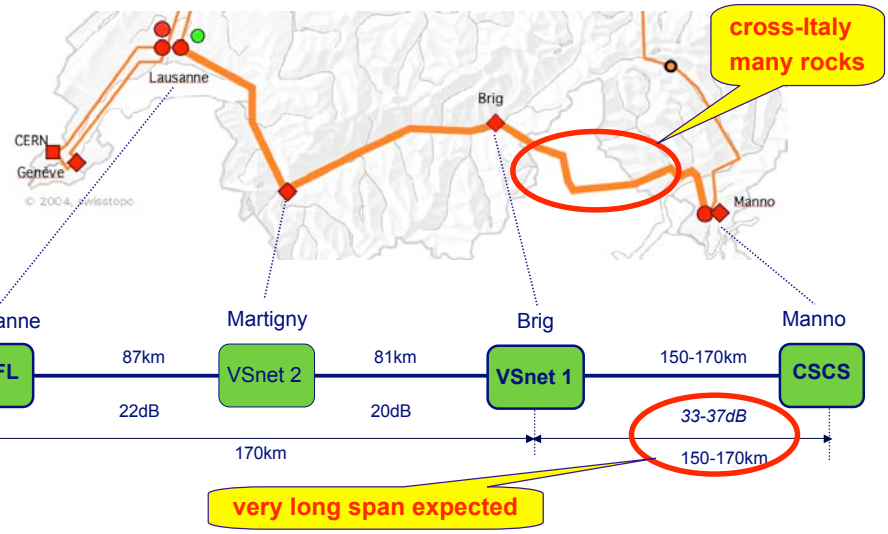
SWITCHlan IP Topology



- topology: highly meshed, 10Gbps on main rings
- direct IP links between major sites
- many IP links share common fibers

Initial plan: 10GE link Lausanne - Manno

geographical situation:



fibers & sites:

planned backbone link on fiber #2:

Realized: 4x10GE link Geneva - Manno

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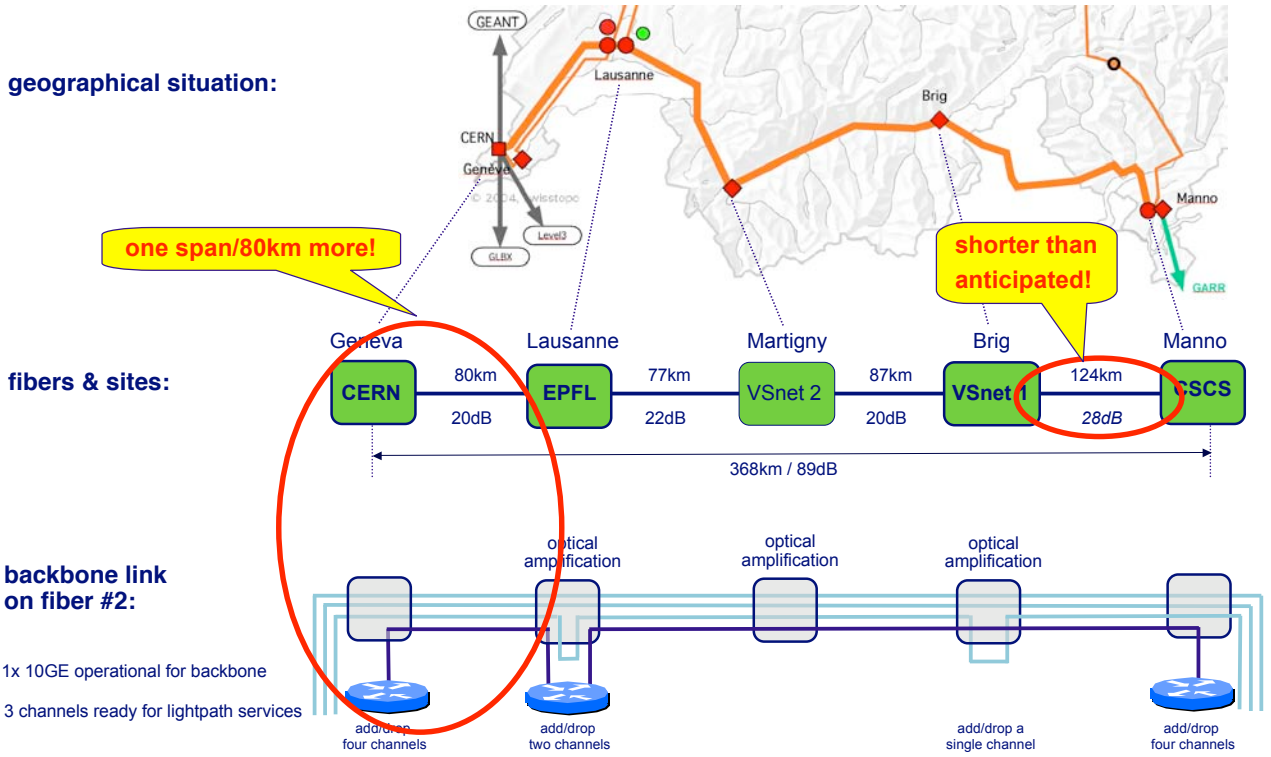

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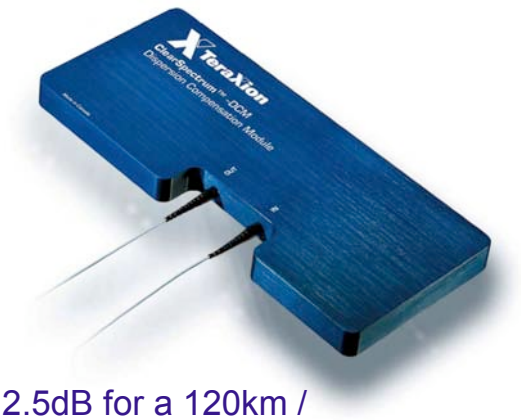
“Same, same (but different)” ?

- the CWDM way - no way!
  - number of available lambdas would be sufficient, but
  - does not support spans with excessive lengths
  - does not support regeneration-free cross-country links
  - 10G CWDM optics are not yet there anyway
- classical DWDM options:
  - continue with Sorrento equipment
  - Nortel, Alcatel, Adva, Ciena, etc - tender for other vendor’s gear
  - but: no new features requested, all comes down to price!
- do-it-yourself approach
  - project good experiences made with GBIC/SFP technology into 10Gbps space
    - use DWDM XENPAK modules
    - assemble optical link infrastructure (amplifiers, filters, compensators) from mixed vendors components
    - use components with good performance/price ratio

Compensation of chromatic dispersion



Fiber Bragg Grating DCMs!

- smaller sized than fiber based DCF
- low attenuation compared to DCFs (typically 2.5dB for a 120km / 2200ps/nm*km module)
- price independent of amount of compensation (and lower)
- broadband modules available covering complete C-Band
- compensation works only at certain lambdas (e.g. 100GHz raster)

some risks did exist

- highly non-linear devices, prone to surprises?
- new - not yet tested in multi-span DWDM networks

Compensation of chromatic dispersion (2)

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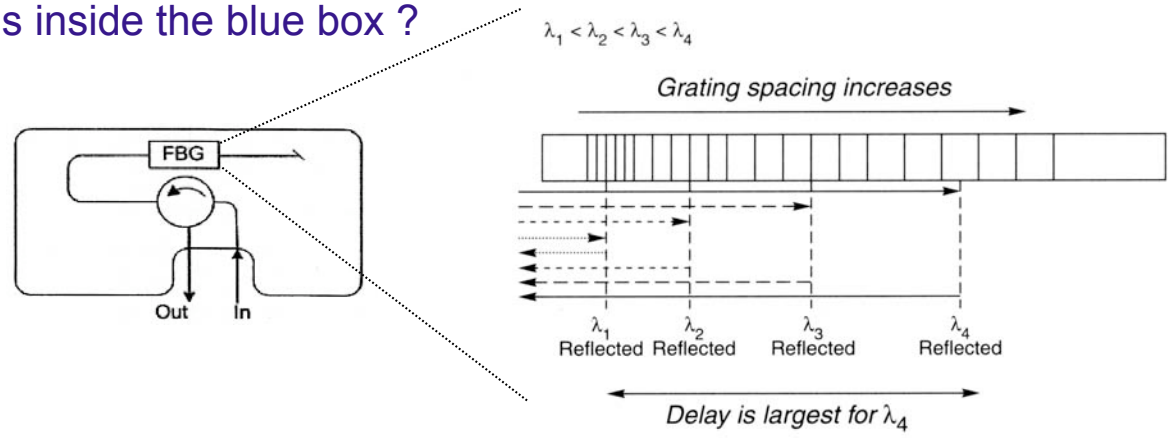
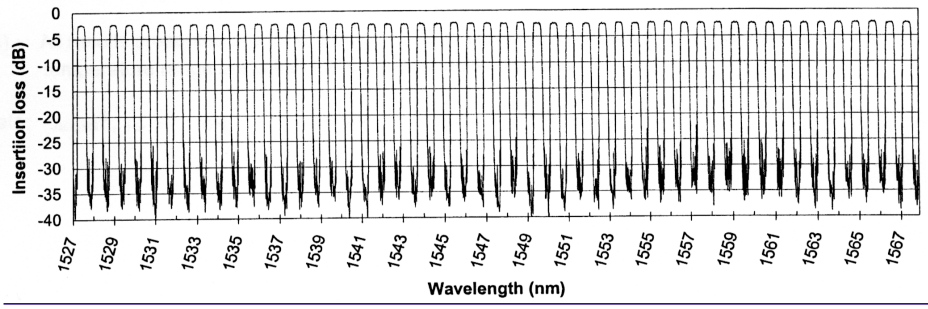
what's inside the blue box ?





- FBG DCM work only at ITU wavelengths
- slope of dispersion can optionally be matched to the fibers

Optical amplifier modules (OAM)

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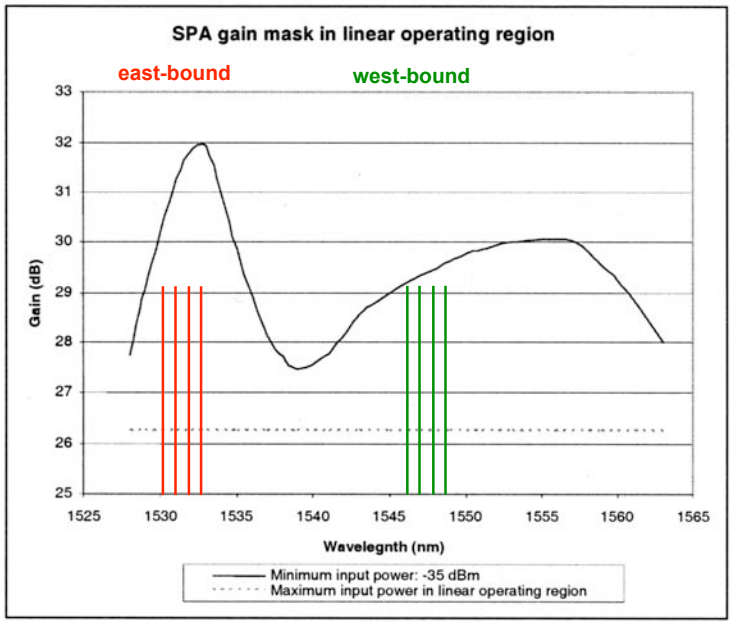
- use of state-of-the-art EDFA amplifiers, with some subtleties
  - buy directly from manufacturer
  - avoid costly general purpose amplifiers
  - use of specialized amplifiers instead
    - high gain, low noise preamplifiers
    - low gain, high output power boosters
  - stick to non-gain-flattened amplifiers which are less complex
    - limited scalability
    - needs some tuning when adding more than a few additional channels
- for our DWDMlight link, we use
  - amplifiers from bti photonic systems Inc
  - preamps+boosters
  - non-gain-flattened...

Channel mapping

Figure 3-21 SPA gain characteristics



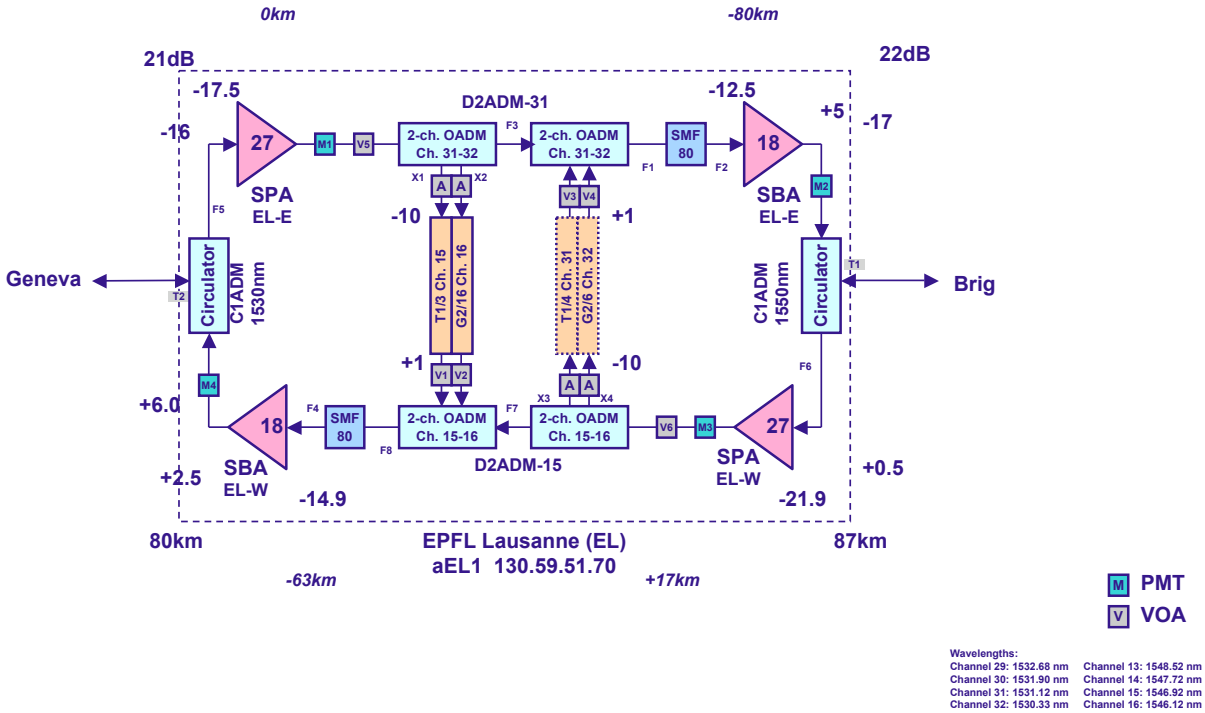
Wavelengths:

Channel 29: 1532.68 nm	**Channel 13: 1548.52 nm**
Channel 30: 1531.90 nm	**Channel 14: 1547.72 nm**
Channel 31: 1531.12 nm	**Channel 15: 1546.92 nm**
Channel 32: 1530.33 nm	**Channel 16: 1546.12 nm**

Optical filters

- two choices:
  - use filters modules from system vendors
    - include shelves
    - easy to install
    - pay for the comfort
  - buy filters as components from manufacturer
    - may or may not come with pigtails
    - need integration is some shelf
    - less expensive
    - might require Chinese language skills
- for our DWDMlight link, we
  - started with components bought from manufacturer
  - finally used bti filters (fitted in existing amplifier shelves)

DWDMlight node design



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DWDMlight realization timeline

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early 2004
- testing on empty SWITCHlan fiber
  - 210km (95% G.655 fibers)
  - single GE NIL
  - Cisco CWDM plug-in modules
  - one bti line amplifier on each sender side

Sep 2004
- revised project plan
  - consider a few channels instead of just a single one
  - asked Cisco for DWDM XENPAK samples

Jan 2005
- testing in Cisco's Monza Labs
  - offered to us as substitute for promised DWDM XENPAK samples
  - setup modeled after expected fiber topology
  - exclusive use of Cisco ONS components
  - no comments regarding use of FBG DCM

1H2005
- decision finding
  - DWDMlight draft design
  - evaluation of alternative solutions

DWDMlight realization timeline (2)

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Jul 2005
- decision to realize mixed-vendor DWDMlight, orders issued

4Q2005
- finalization of DWDMlight design
  - switched to using bti DWDM filters
  - switched to partially using teraxion DCMs in bti modules (easier assembly)
  - as consequence more in-depth bti support for design

Jan 2006
- lab installation at Sunrise's premises
  - fiber spans replicated with real fibers
  - all nodes properly wired for later installation "en bloc"
  - minor issues with "circulators" corrected
  - chase for origin of bit errors - turned out to be our test setup!

April 2006
- field installation
  - installation at SWITCHlan sites, 3 days for 5 sites
  - BER testing
  - start of productive service

DWDMlight lab installation

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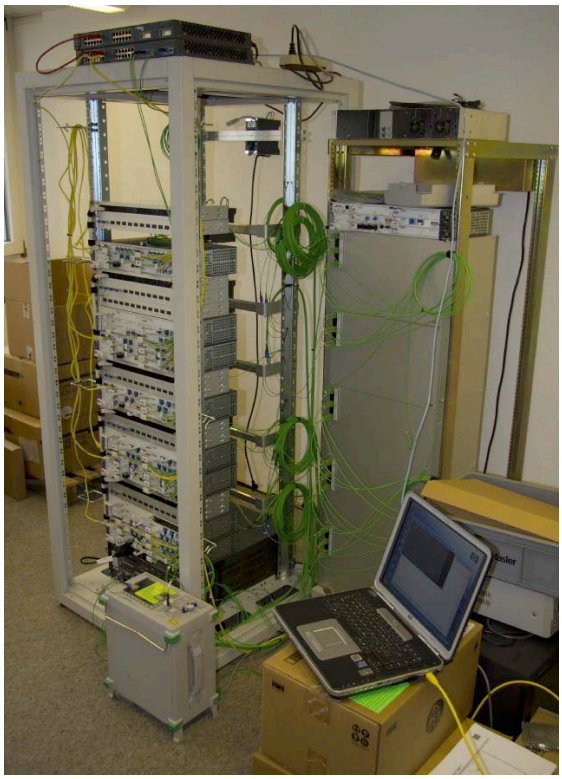
- intensive lab testing was deemed crucial as many new components were used
- design & testing done by Chris Watts from Sunrise Wireline & Internet in Bern
- support during design & testing worked well with both bti and Teraxion
- all five nodes easily fit into one 19” rack
- 48V DC power supplies can be placed behind bti shelves
- 360km of fibers on spools are placed in a separate rack



DWDMlight shelves

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DWDMlight installation Lausanne

- typical intermediate node
- 2 channels add/drop
- items top-down:
  - space for cable reserve
  - taps, VOAs (in tray)
  - bti shelf1: DCMs, filters
  - bti shelf2: controller, OAMs, circulators
- 48V DC power supplies mounted in the rack’s rear

Experiences, expectations...

- lab testing to prove BER < 10E-15
  - links modeled with G.652 fibers on spools
  - connector attenuation simulated by attenuators
  - nodes were properly wired in the lab and then moved to the sites “en bloc”
- robustness - how much margin do we have (@4 channels lit)?
  - worst span has 5dB margin - due to savings in Martigny site (no boosters)
  - longest span has 9dB margin!
- first operational experiences
  - not a single problem so far
  - SNMP now implemented, but only traps, no polling yet!
- going beyond the four channels ?
  - non-gain-flattened amplifiers limit the capability to grow (per design!)
  - going up to 8 channels seems easily feasible
    - requires some tuning at intermediate nodes
    - the addition of two booster amplifiers in Martigny

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Two ways to do it - leasing dark fibers

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	one stop shopping - all fibers from one source	fiber links concatenated from multiple sources
pros	convenient • fiber provider does all the planning & setup • one contact to complain if fibers break	know-how builds up within NREN better knowledge • where our fibers pass through • local contacts (for emergencies) better reconfiguration flexibility lower total price for fiber lease
cons	inflexible • e2e links cannot easily be reconfigured expensive • Providers don't do their coordination work for free	more demanding planning & deployment requires e2e fiber testing after assembly of multi-provider spans need for gear and staff to localize fibers breaks (can be out-sourced)

2001-2003 with external support to acquire fibers → **SWITCH** → 2005

Two ways to do it - equipment

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	classic single vendor solution	multi-vendor solution with plug-in optics
pros	complete, operational system including transponders vendor is responsible for • proper design • installation & initial configuration • maintenance (often mandatory) vendor guarantees delivery of service	10Gbps plug-in optics • cheaper than standalone transponders • monitoring integrated in L2/L3 platform buy where price & performance is best • optical amplifiers • optical filters • dispersion compensation modules better optimized price/performance ratio build-up of know-how within NREN
cons	know-how remains with vendor vendors reluctant to open their systems (like for alien wavelengths) rather expensive • pay for unneeded features • pay for brand support contracts often overprized	10Gbps plug-in optics • hard to get • still limited feature set responsibility for design, installation, configuration, operation is with NREN external support might be needed (system integrator)

2001-2003 → **SWITCH** → 2005

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Kind of a summary...

what we built is a low cost DWDM system

- 370km long, spans up to 125km
- designed for 4 channel of 10Gbps
- upgradable to 8 channels with reasonable effort

what it took is

- plug-in optics, filters, amplifiers, compensators from multiple vendors
- product support from those vendors
- engineering support for design, integration, testing, roll-out
- will & courage to take some risk - no “money back guarantee” !
- flexibility in terms of start of service date

what we got is

- a smoothly running system at a good price
- much more insight into the design of optical transmission systems
- prove that we can roll-out custom-tailored solutions in the 10Gbps range without being experts!

And now some entertainment...

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There is no better thing than watching others at work...

road work between Varzo and Iselle (Italy)

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