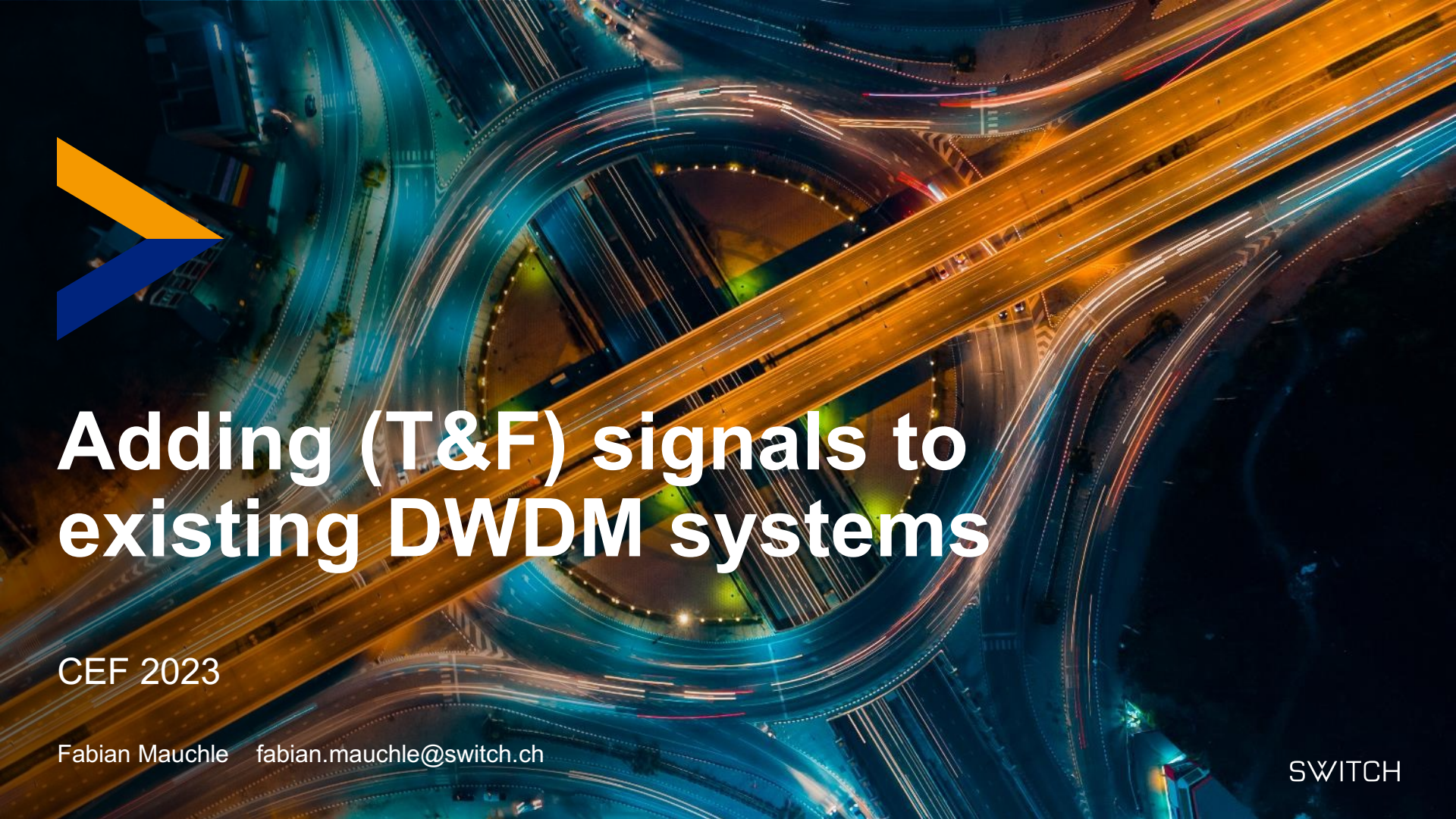


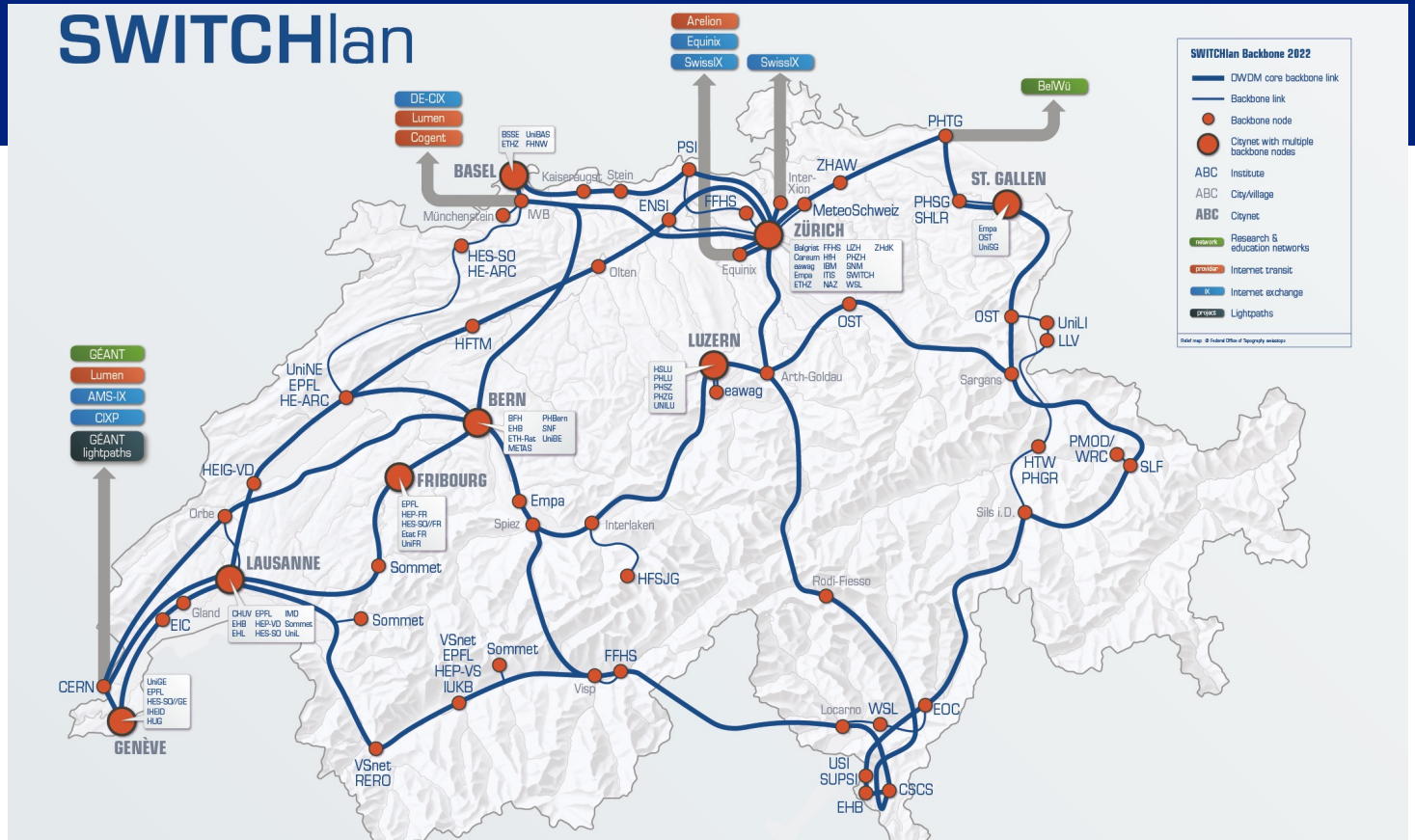
Adding (T&F) signals to existing DWDM systems

CEF 2023

Fabian Mauchle fabian.mauchle@switch.ch

SWITCH

Context



*beeline

SWITCH

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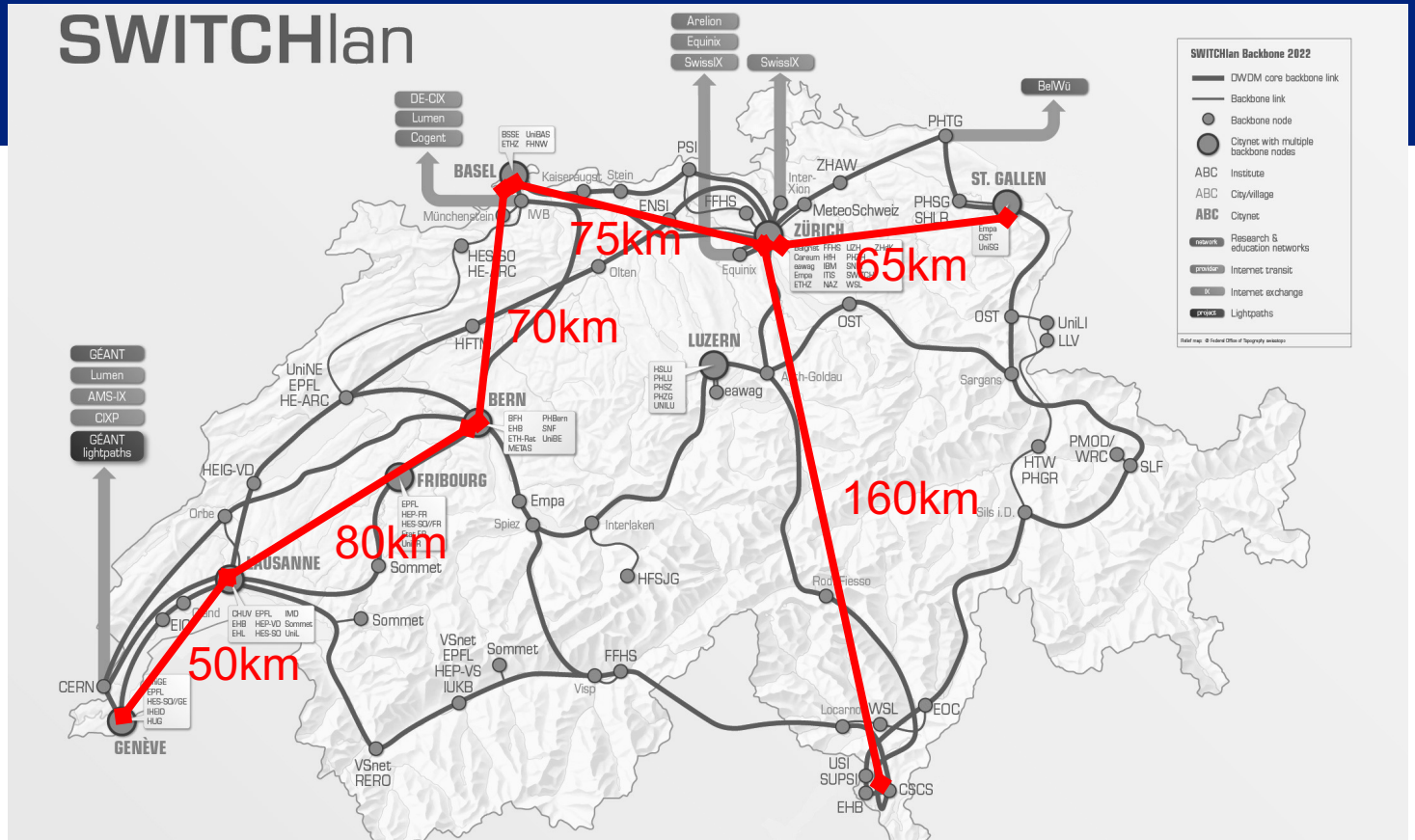
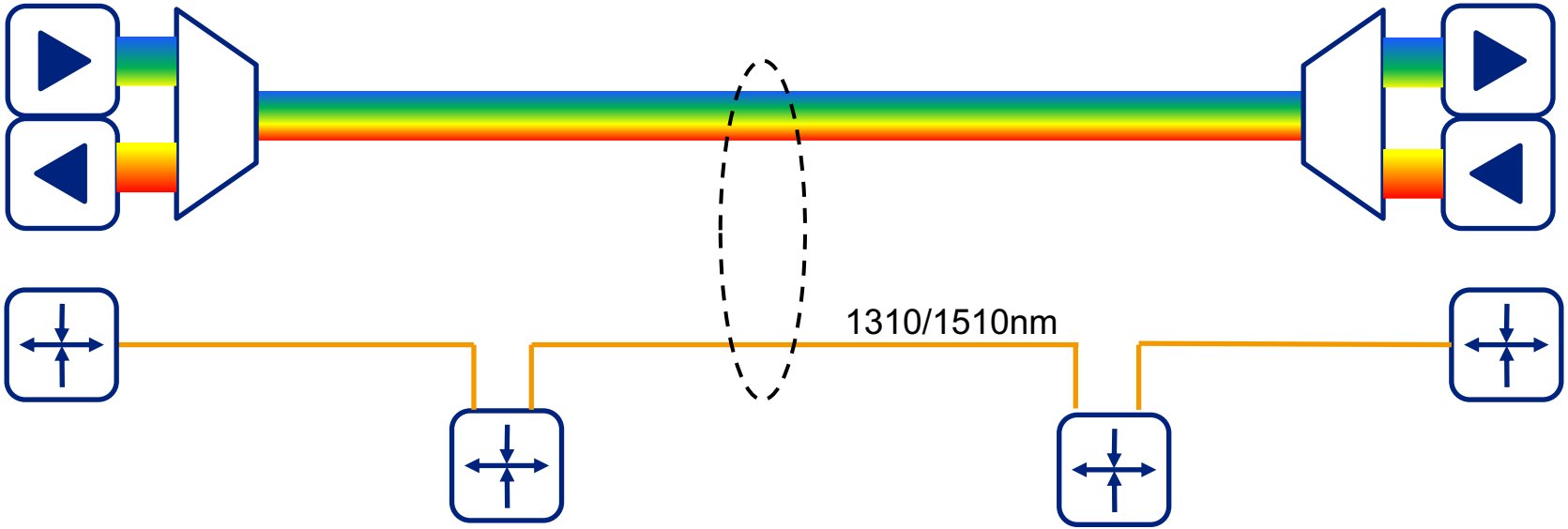


*beeline

SWITCH

History

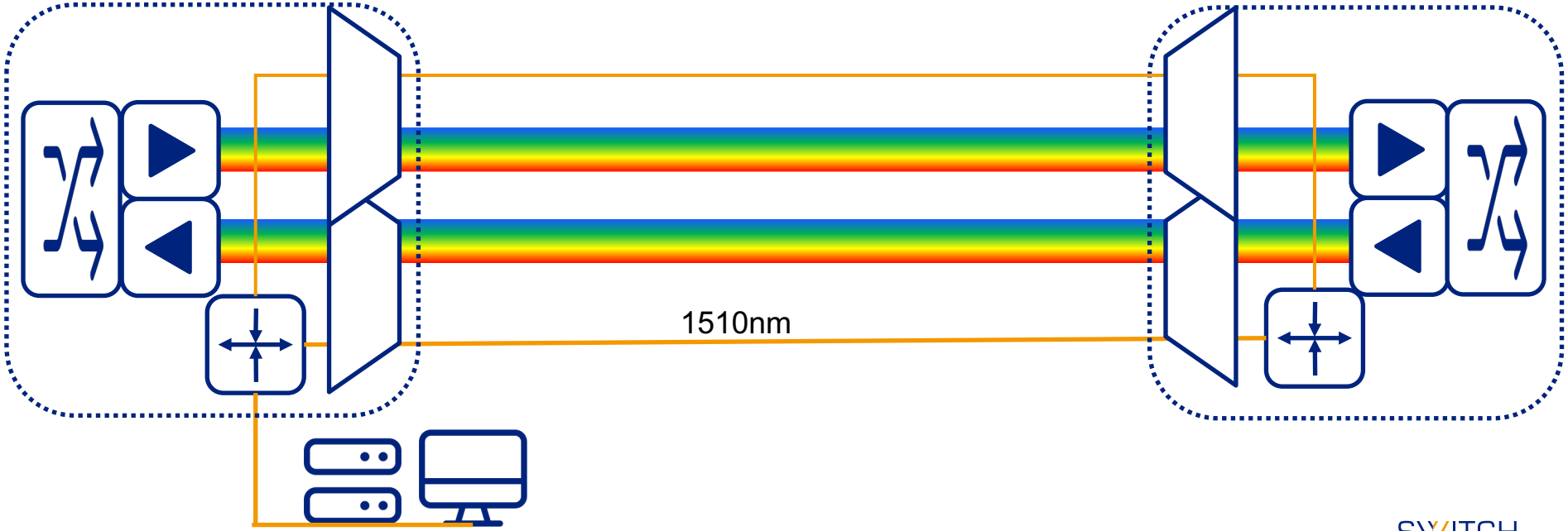
→ SWITCH started own fiber network in 2001
→ Fibers rented in pairs
→ Bidir DWDM on first fiber
→ Intermediate hops on second fiber



SWITCH

History

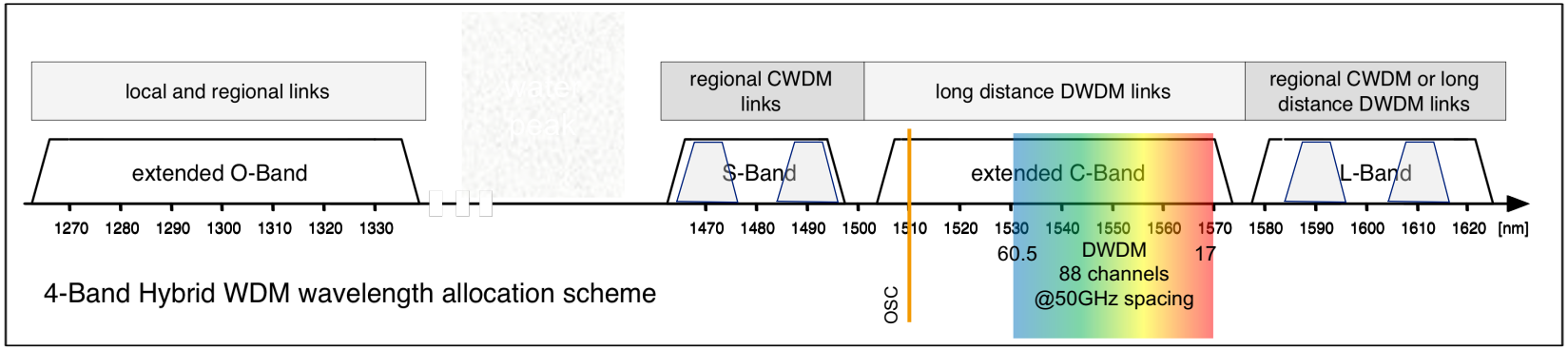
→ New DWDM system in 2013
→ Colorless/Directionless Flexgrid ROADM system
→ Requires dual fiber

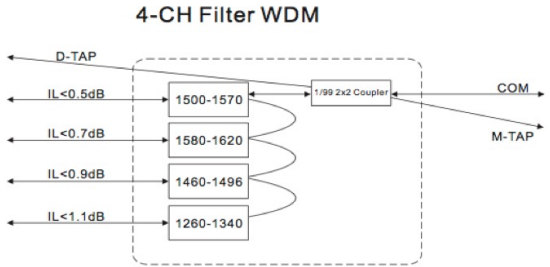


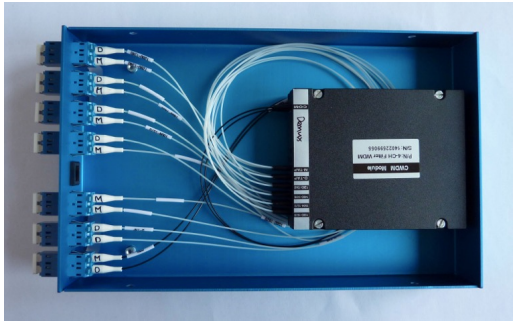
SWITCH

HWDM

→ Combine **D**WDM with **C**WDM -> **H**ybridWDM
→ Actually a band-filter
→ O, S, C+, L –band
→ Add 1.25dB loss in planning (5dB total for 1 intermediate hop)





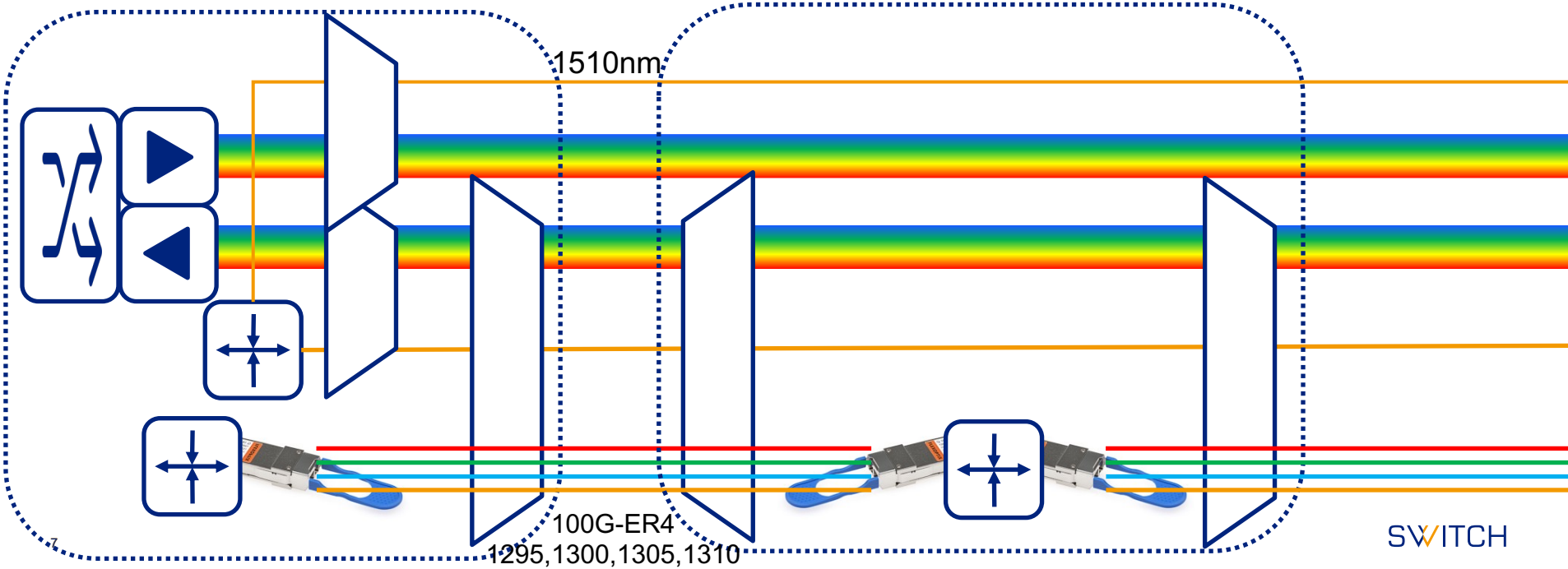


SWITCH

New usecase: 100G ER4

→ Long (>10km) 100G only as coherent DWDM
→ Use O-band of HWDM system for shorter links
→ In theory even ~70km (100G-ZR4) possible
→ Still hoping for QSFP-28 coherent DWDM (or CWDM?)

*only one fiber shown in full detail



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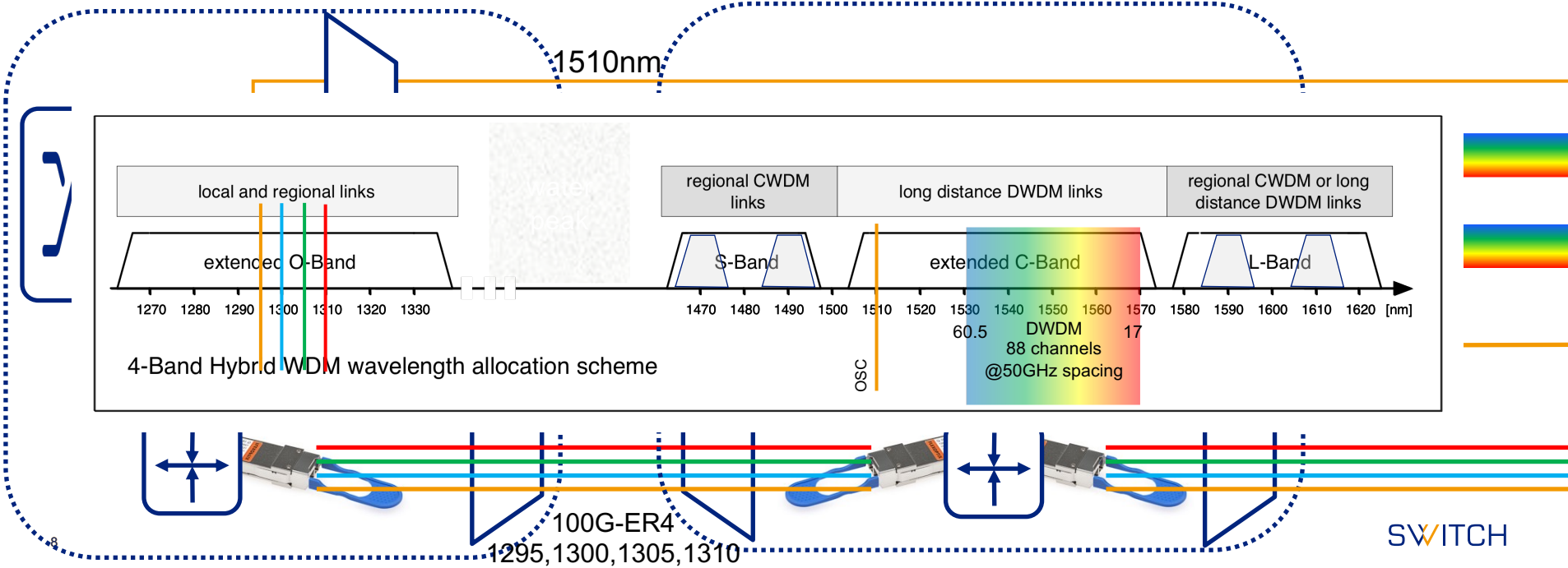


SWITCH

Exotic: Time & Frequency

→High accuracy Time & Frequency signals **MUST** be bidirectional

→Inconvenient to combine with dual-fiber DWDM
  →Especially CD(C) Flexgrid ROADM
  →Everyting else uses tunable lasers

→C-band is ‘owned’ by DWDM, don’t want to interfere.

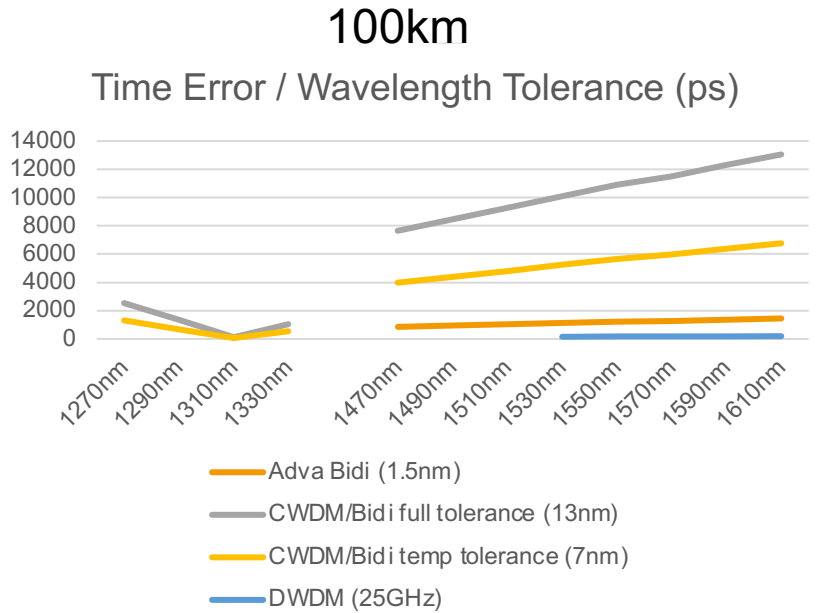
White Rabbit

- → Invented at CERN
- → Extension to PTP
- → Designed for campus using bidir SFP
- → Sub-ns accurate

- → Time sync: Need to measure RTT
- → Forward/backward delay should be equal
  - → Or known asymmetry

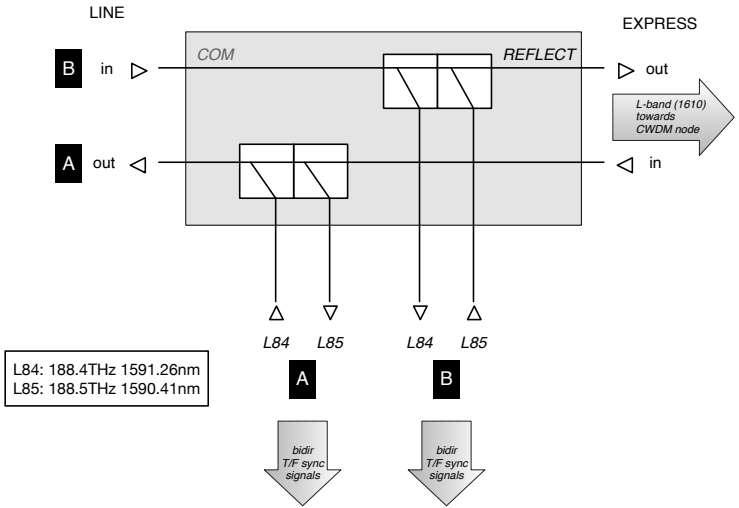
- → Normal 1G Ethernet, with SFPs
  - → Can use any SFP, (maybe add bidir OADM)

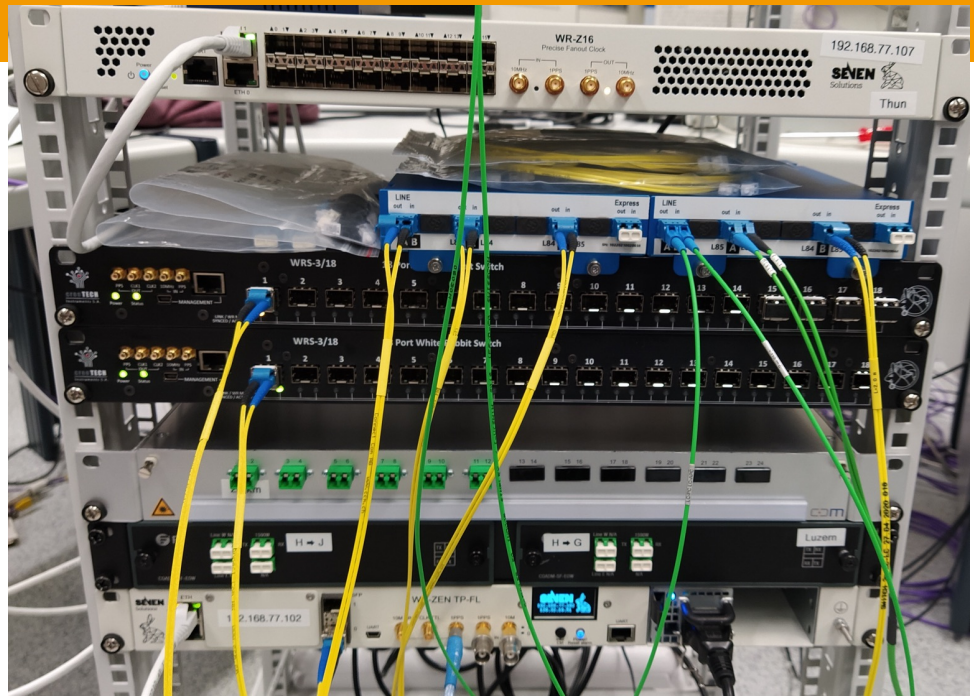
- → Minimize asymmetries
  - → Bidirectional transmission
  - → DWDM lasers (100GHz spacing)



White Rabbit

→ Combine bidir transmision with normal dual-fiber CWDM
→ get 2 lines at once
→ L-band DWDM
→ **Very hard to source L-band SFP** (as of 2023)





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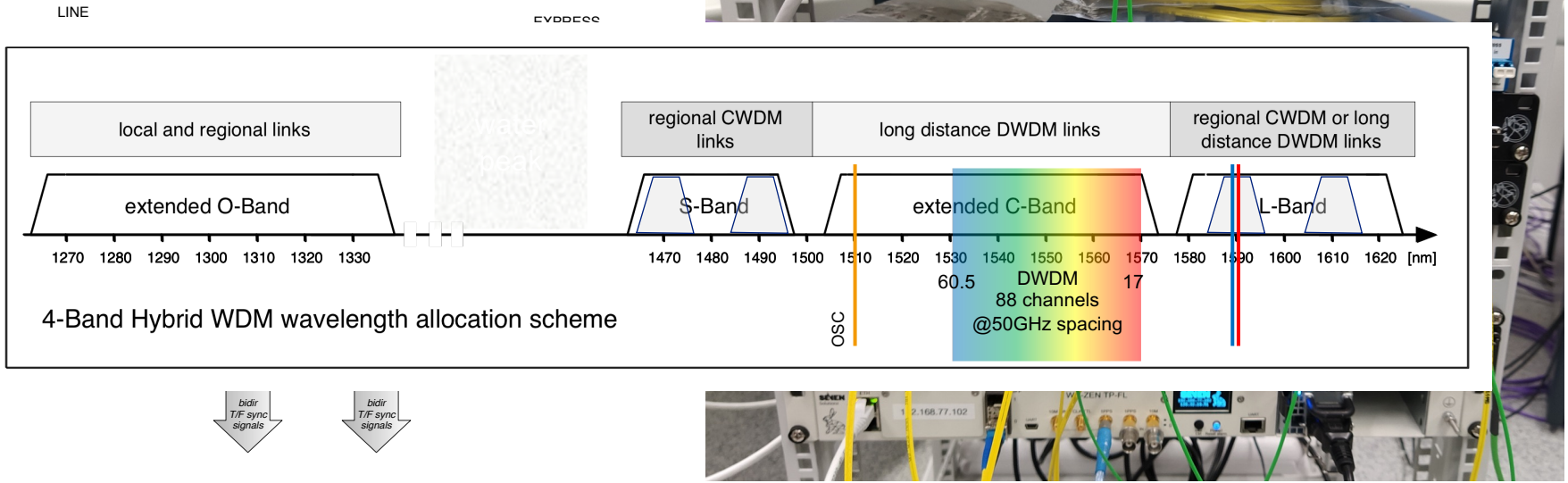
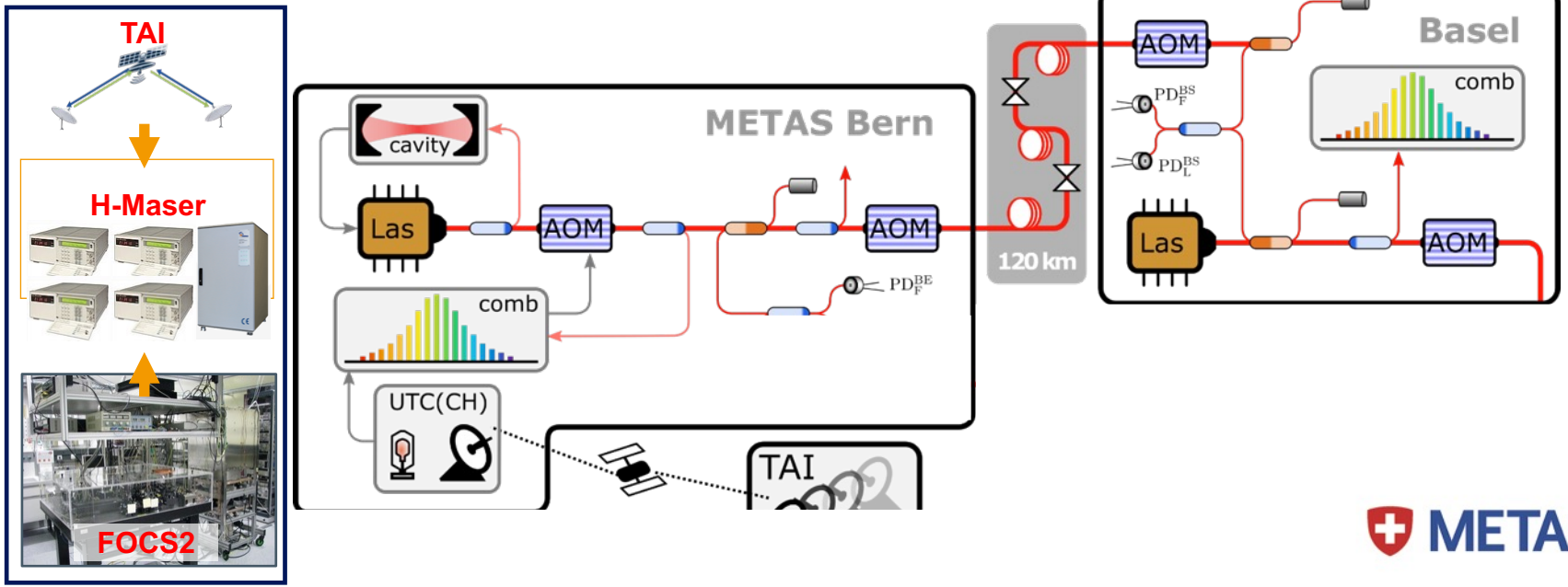


SWITCH

Ultrastable Frequency

→ Transmit primary frequency reference
  → Active H-Maser or Cs-Fountain clock
→ Lock narrow linewidth laser to primary reference using frequency comb
→ CW carrier, no modulation, phase noise cancellation



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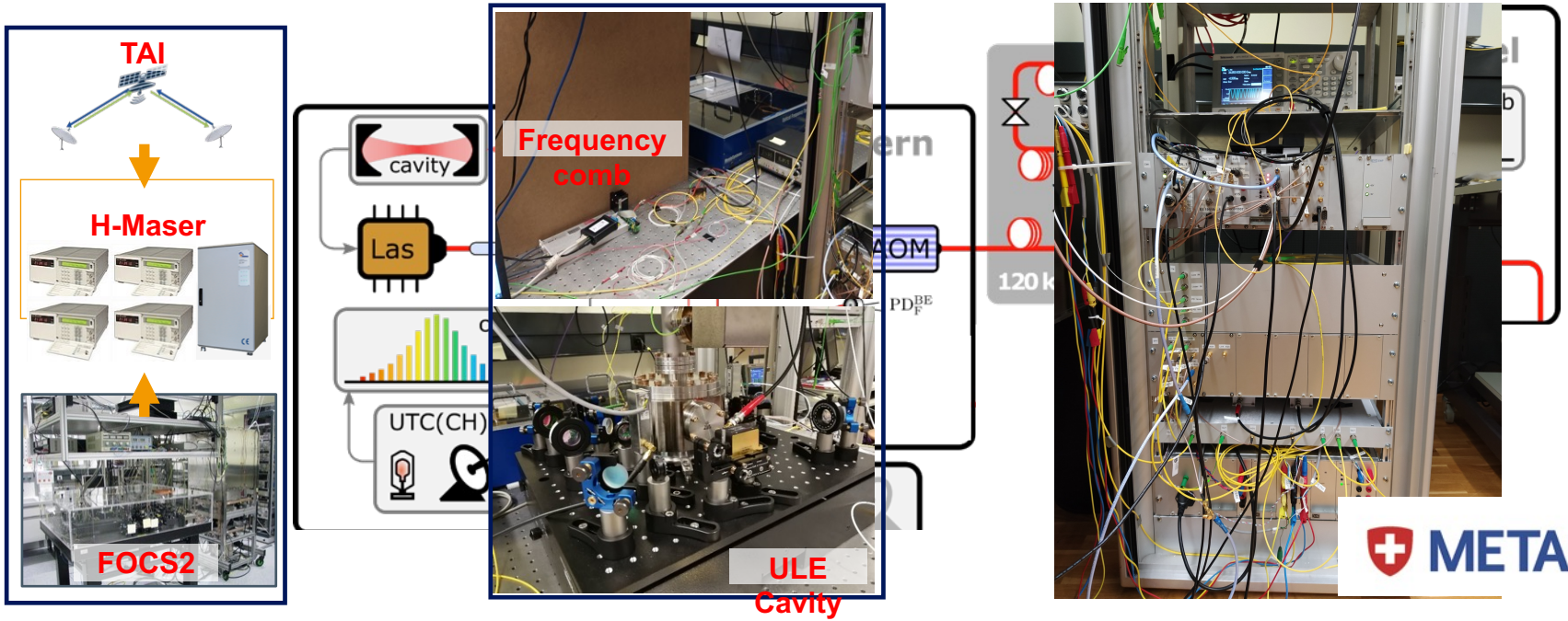
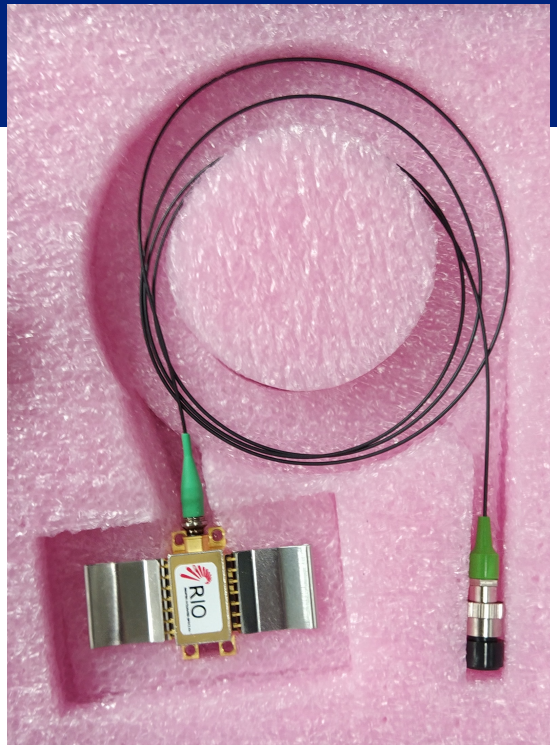


Ultrastable Frequency

→ Mostly implemented for ITU ch44

→ Can this work in L-band?
→ **RIO only confident in ch07 (1572nm)**

	λ agnostic	dependant
→ Frequency comb	✓	
→ Narrow lineweidth laser		**+100k $**
→ AOM	✓	
→ Circulators/splitter/combiner	✓	
→ Photo diodes	✓	
→ OADM		✓
→ Bidirectional amplifier		✓



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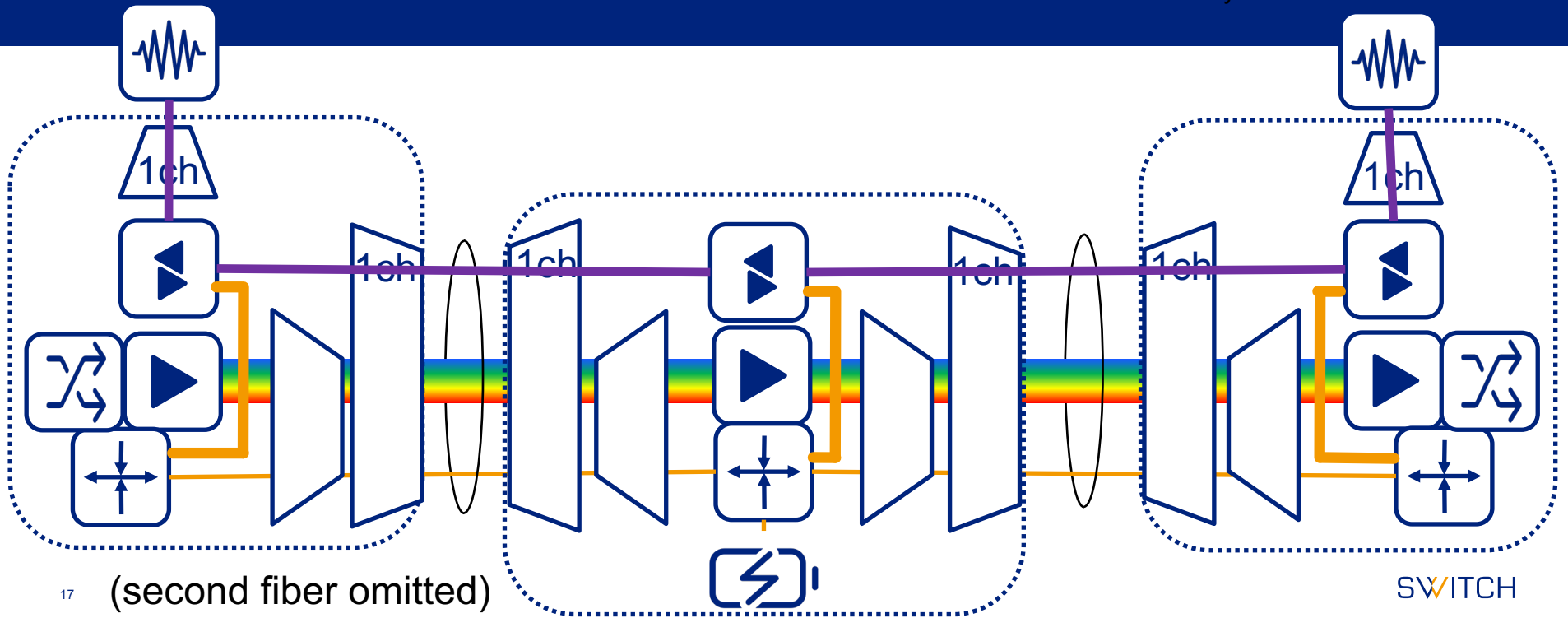
→ OADM		✓
→ Bidirectional amplifier		✓

SWITCH

Ultrastable Frequency

→ Integrate bidir amplifier management in existing DWDM management
→ Bidir spectrum isolation (DWDM OADMs) double as multiplexers
→ RAMAN amplifiers might use midstage extension port

*only one fiber shown in full detail



(second fiber omitted)

SWITCH

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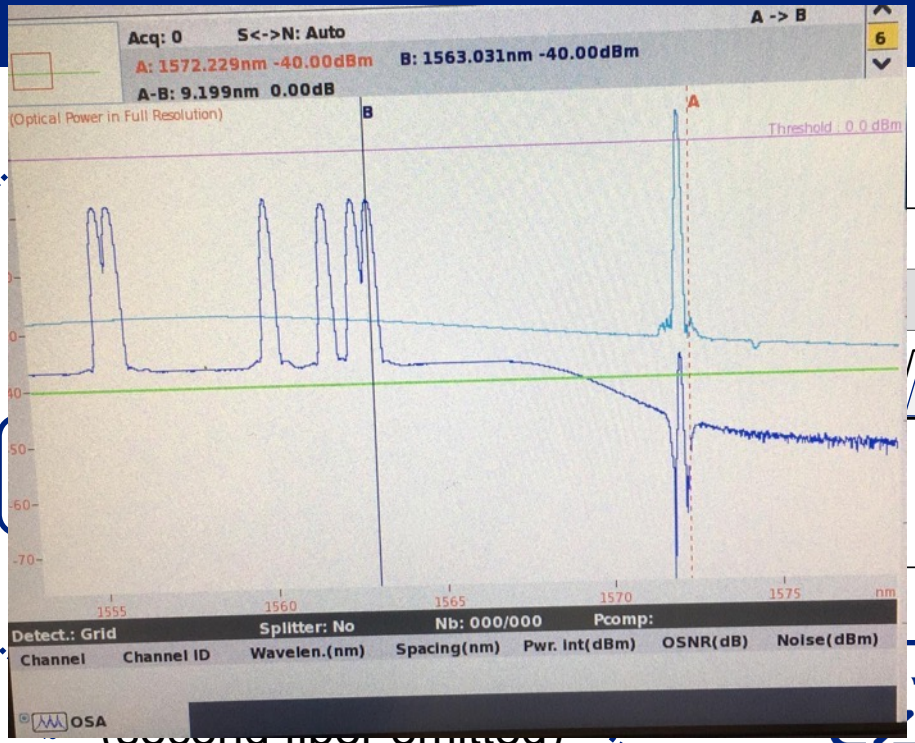
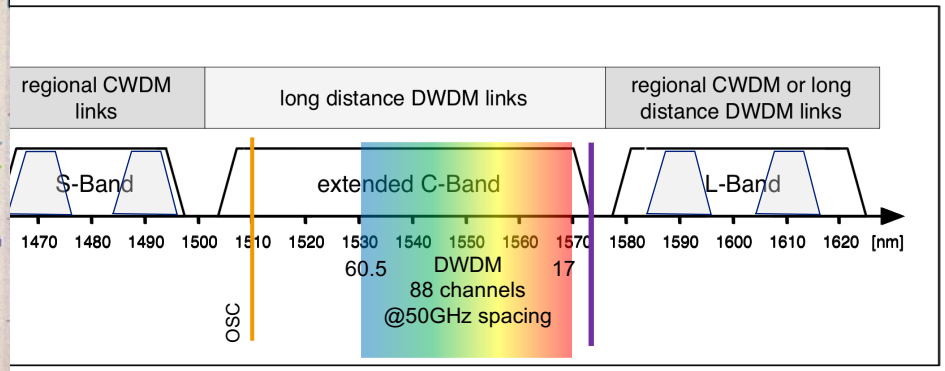




SWITCH

What we've learned

→ Amplifiers need little changes once link is established

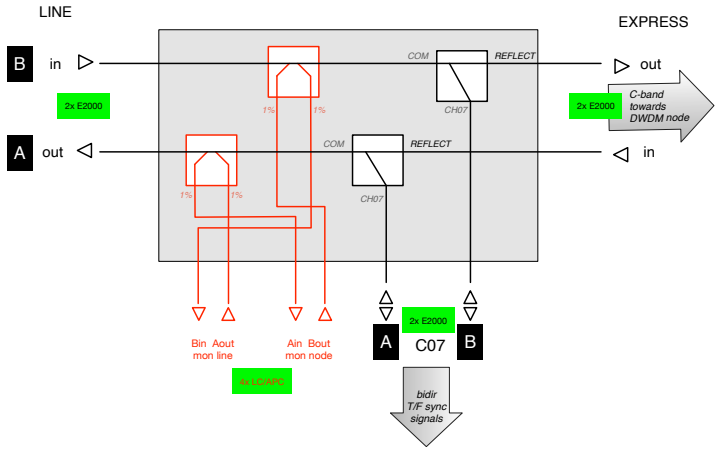
→ Integrate into NOC processes as spectrum service
  → not much insight besides light on/off
  → don't forget notifications when working on shared fiber

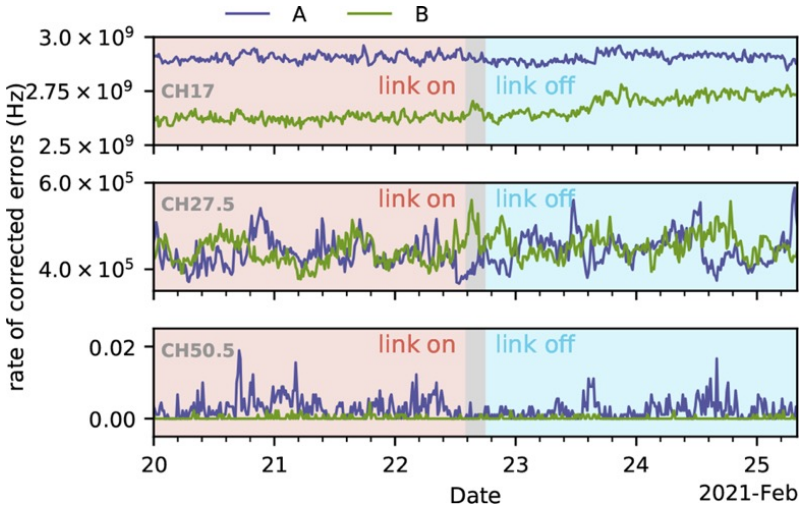
→ Taps on the OADM would be handy
  → debug spectrum (OSA) in-service
  → most DWDM equipment has them

→ This OADM should always be last in the stack
  → Minimize reflections

→ No impact on DWDM system
  (especially coherent transmissions)

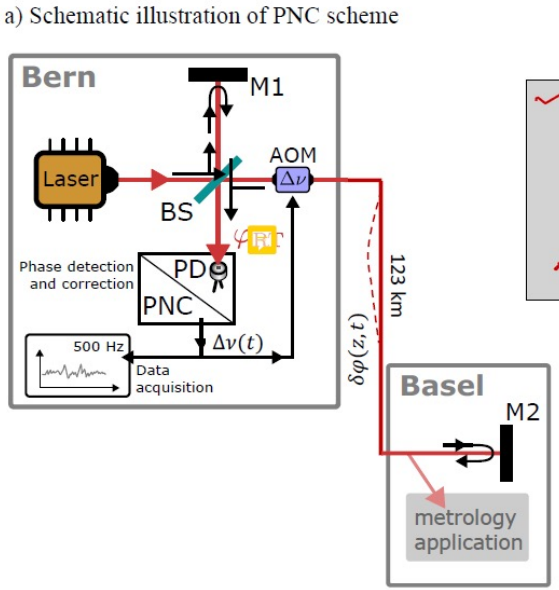
→ **Husmann et al., Optics Express**
  Vol. 29, Issue 16, 24592-24605, 2021
  https://doi.org/10.1364/OE.427921

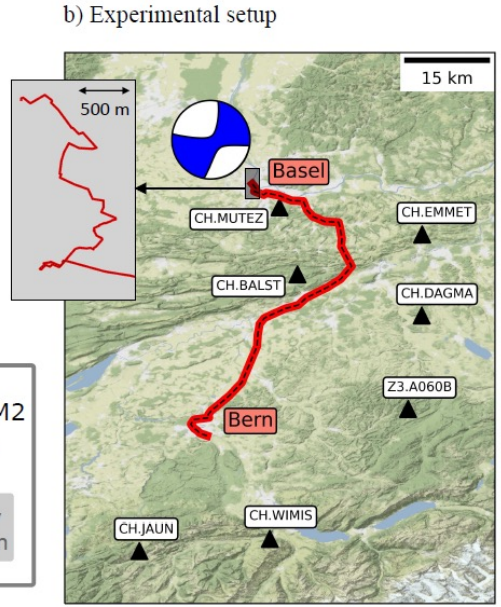


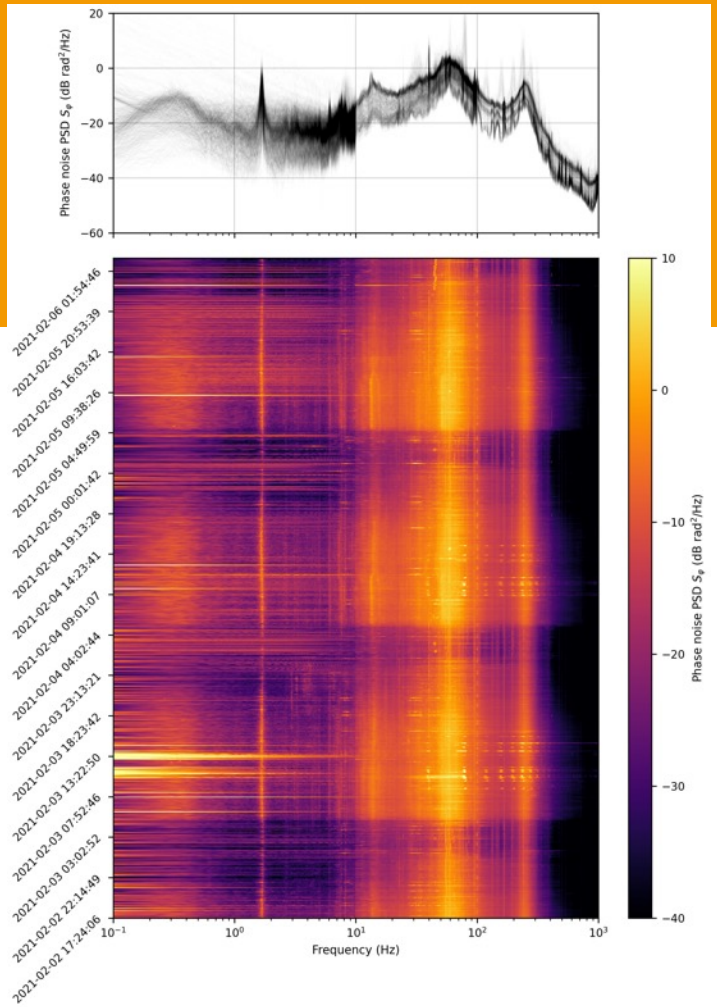


Acoustic noise?

→ 100km long microphone?
→ 100km long seismic sensor?
→ Theoretical model by
Swiss Seismological Service (SED) ETH Zürich

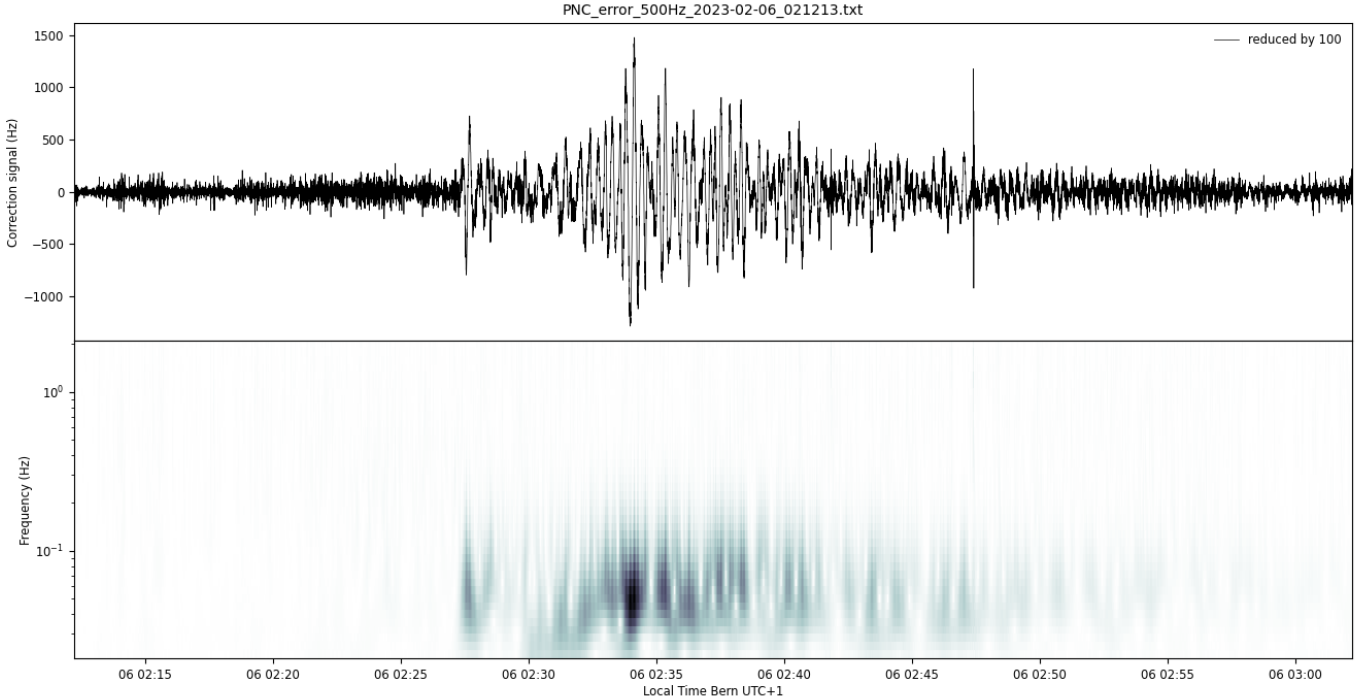






The very sad proof

→ 6.2.2023



SWITCH

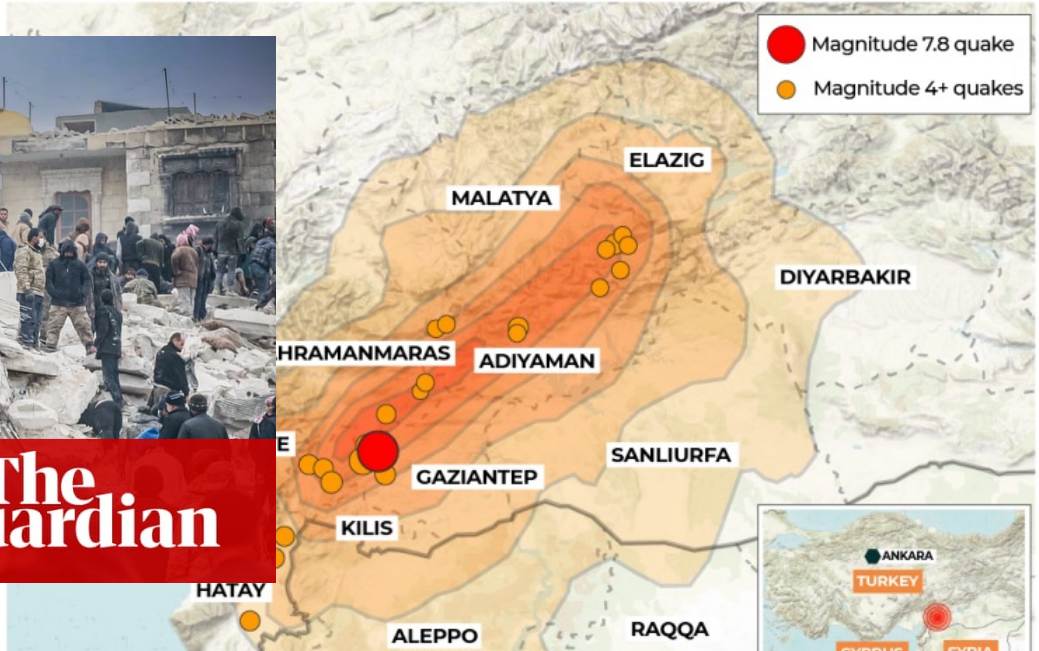
The very sad proof

→ 6.2.2023

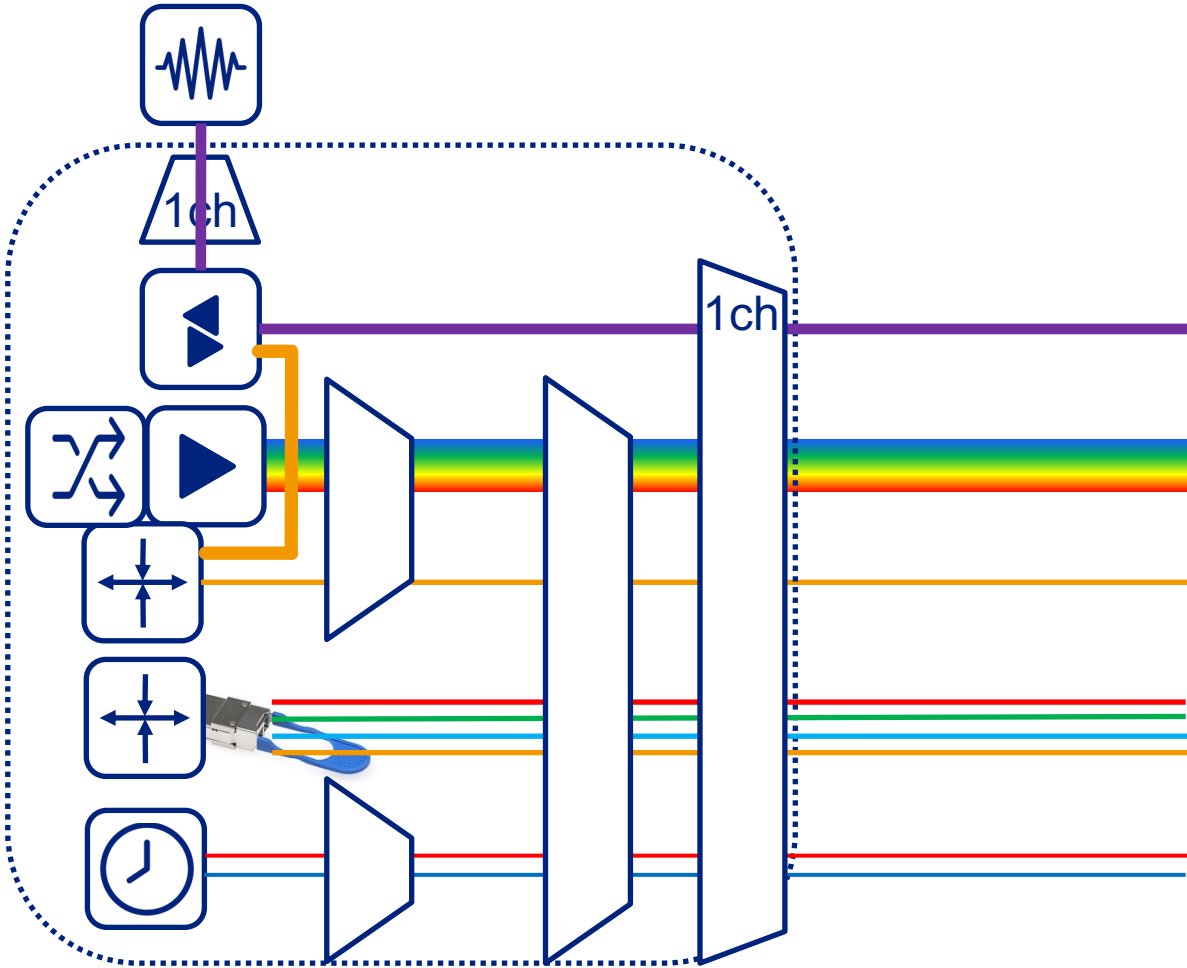
EARTHQUAKE

Hundreds dead in Turkey, Syria earthquake

Hundreds of people are dead and more than 1,700 buildings have collapsed after a magnitude 7.8 earthquake struck the southeastern region of Turkey along the border with Syria. Tremors were also felt across Lebanon and Cyprus.



Putting it all together



SWITCH

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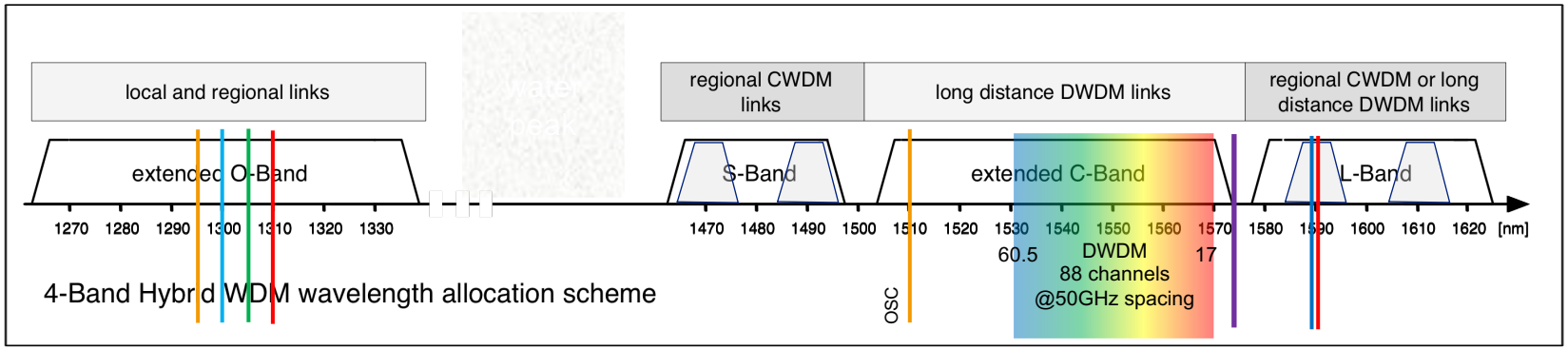

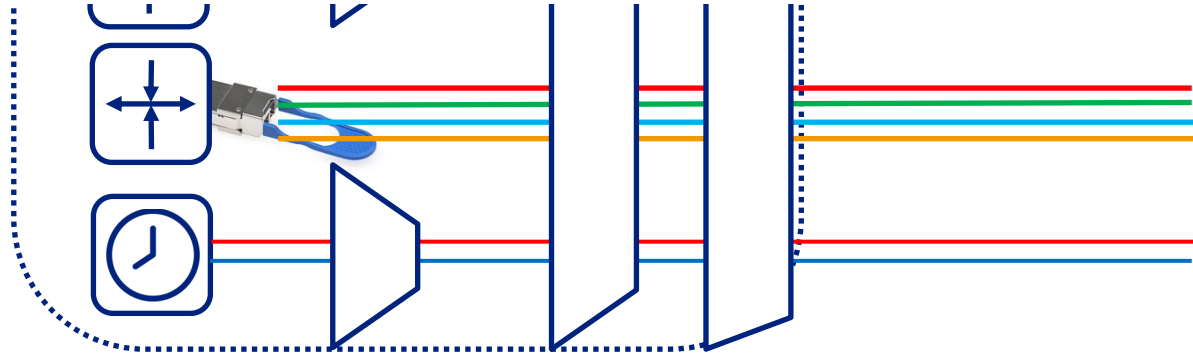

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Questions?

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