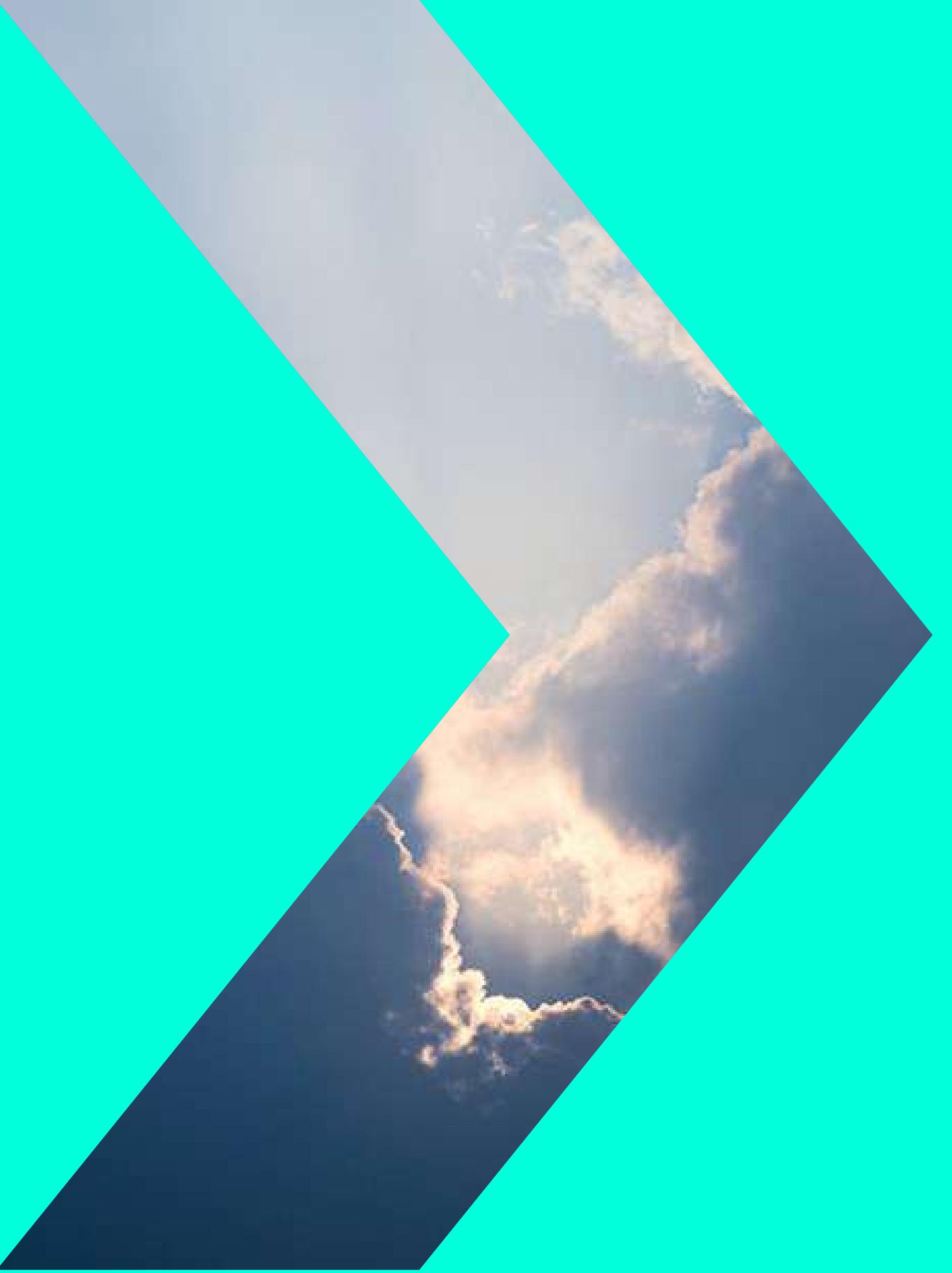


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INDUSTRY-GRADE COHERENT OPTICAL FIBER LINKS : CURRENT STATUS AND FUTURE EXAIL DEVELOPMENTS

G. Coget*, M. Rabault, V. Ménoret, P. Rosenbuch and B. Desruelle

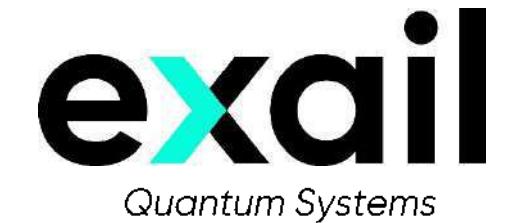
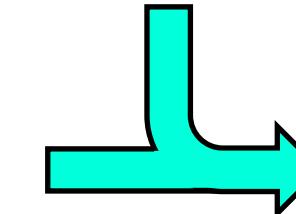
Exail Quantum Systems (former Muquans) – Bordeaux, France

gregoire.coget@exail.com

- 1. Exail Quantum Systems**
- 2. Industrial grade frequency transfer network**
- 3. Future of fiber links division activities**

Exail Quantum Systems

➤ Who are we?



Company created in 2011
Spin-off from 2 French labs



Incorporated in June 2021
32 people

Incorporated in September 2022
39 people

➤ Our main products



Atomic clock

$$\Delta f/f \approx 10^{-15}$$



Regeneration Laser Station

$$\Delta f/f \approx 10^{-20}$$



Intelligent Laser Systems

$$\Delta\lambda/\lambda \approx 10^{-10}$$



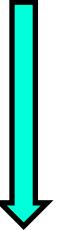
Absolute Quantum Gravimeter

$$\Delta g/g \approx 10^{-9}$$

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Optical Fiber Links Team

- Technology transfer (2014)



Syrlinks 

- Our Partner in REFIMEVE:



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- Develop the repeater station and extraction stations
- Deploy the equipments on RENATER network

- Day-to-day operation and supervision of the frequency transfer network

Since 2022

- Develop the multi-branch laser station (MLS)

INDUSTRY - GRADE NETWORK

The Repeater Laser Station

- Works in the C (CH #44) and L band (CH #07)
(**1542.14 nm and 1572.063 nm**)
 - Automatic polarization optimization
 - Thermally controlled interferometer : sensitivity (**<1 fs/K**)
 - Uses narrow-linewidth local laser diode (**< 5 kHz**)
 - Low-noise heterodyne detection **SNR > 90 dBc/Hz**
 - Needs very low input optical power level (**few nW**)
- 

A big technology challenge

➤ Equipment

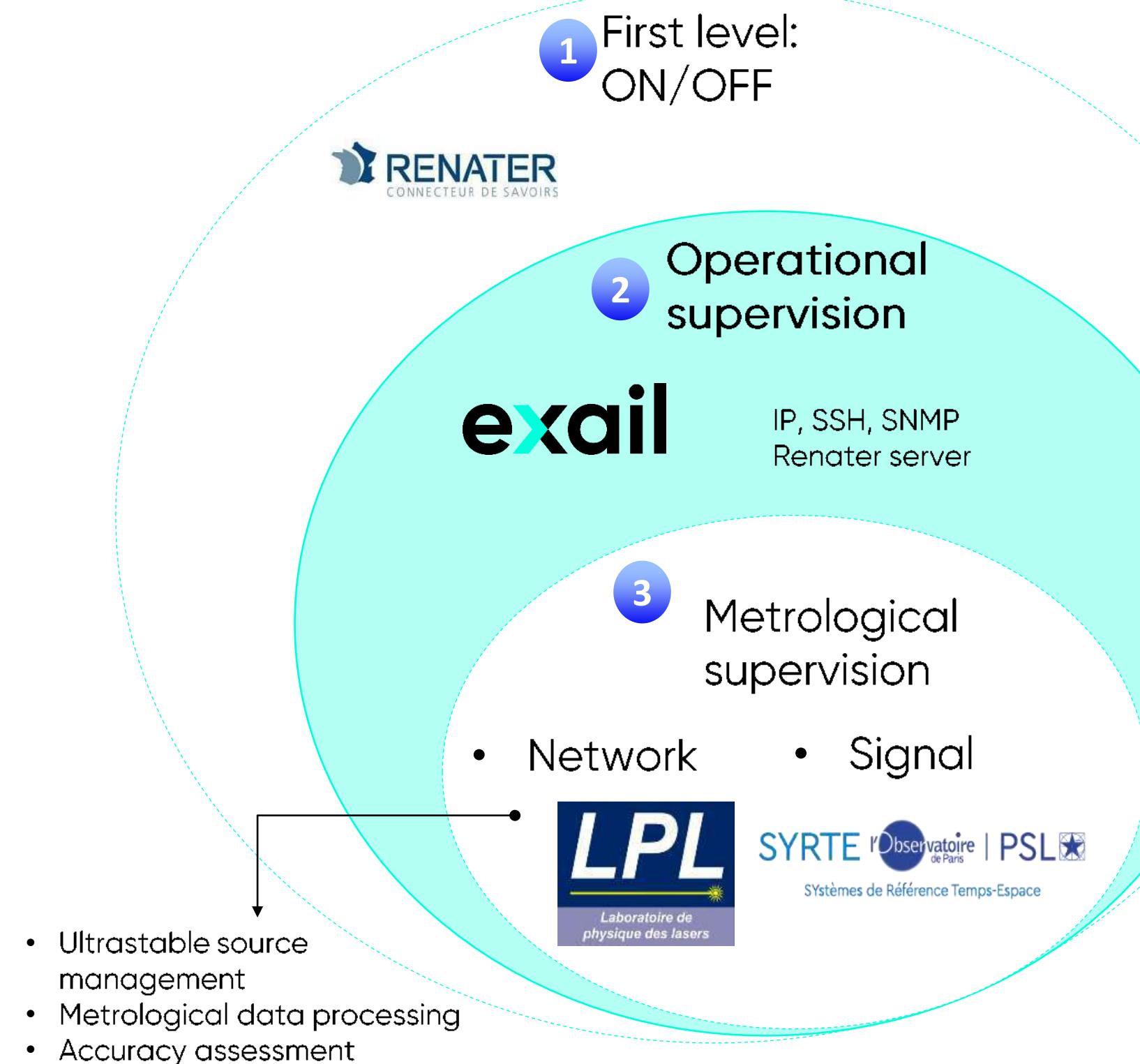
- High-performance level and good reproducibility : **50 state-of-art RLS**
- Reliability and robustness TRL 9
- Cost and delay control: **6 months of production**
- Remote control and autonomy

➤ Network Supervision

- Different type of equipment to monitor (EDFA, RLS Superstation, frequency counter)
- Save and analyse large amount of data



Network Supervision

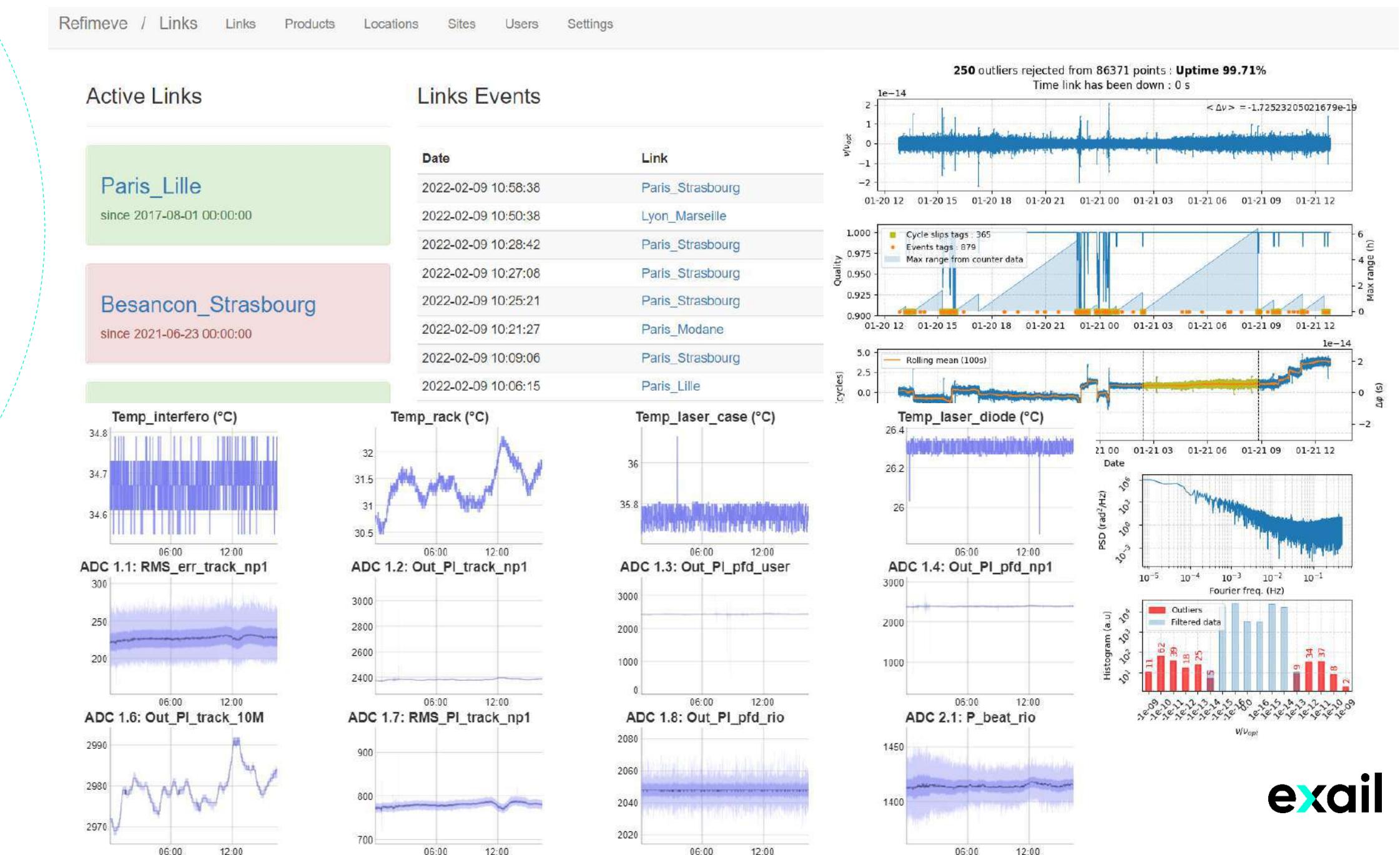


• Supervision software:

- ✓ Monitor equipment parameters in real-time
- ✓ Detect and manage bugs/alarms (cycle slips, polarization optimizations, ...)
- ✓ Data pre-processing
- ✓ Friendly-user HMI

• Database:

- Alarms/events stored
- Equipment management



Industry - grade frequency transfer network

➤ 7 links deployed (2 x 3300 km)

- 2 recent links Paris – Bordeaux and Grenoble – CERN

➤ Fast deployment

- Around 1 week for a link

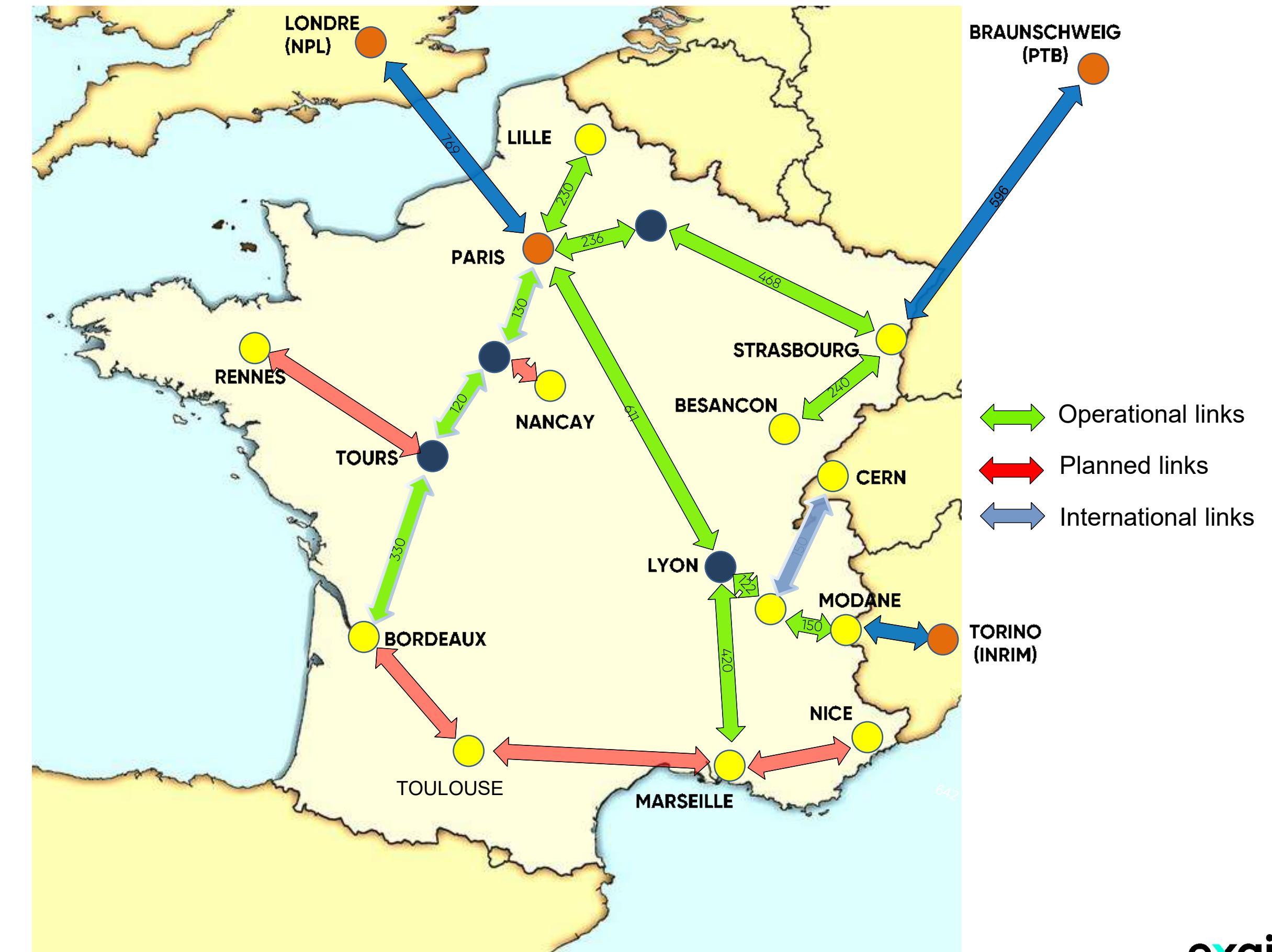
➤ High availability of the metrological signal

- Day : 99%
- Month : 90%
- Year : 70%

➤ Fully autonomous equipments

➤ Several equipments dispatch

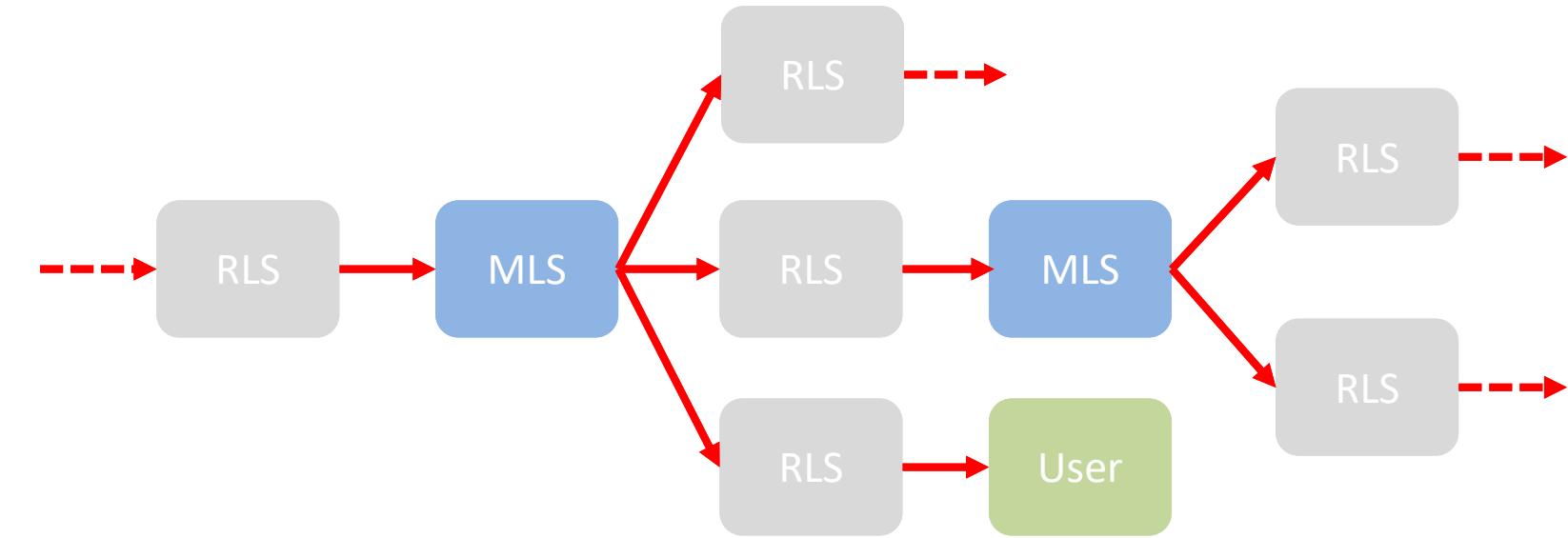
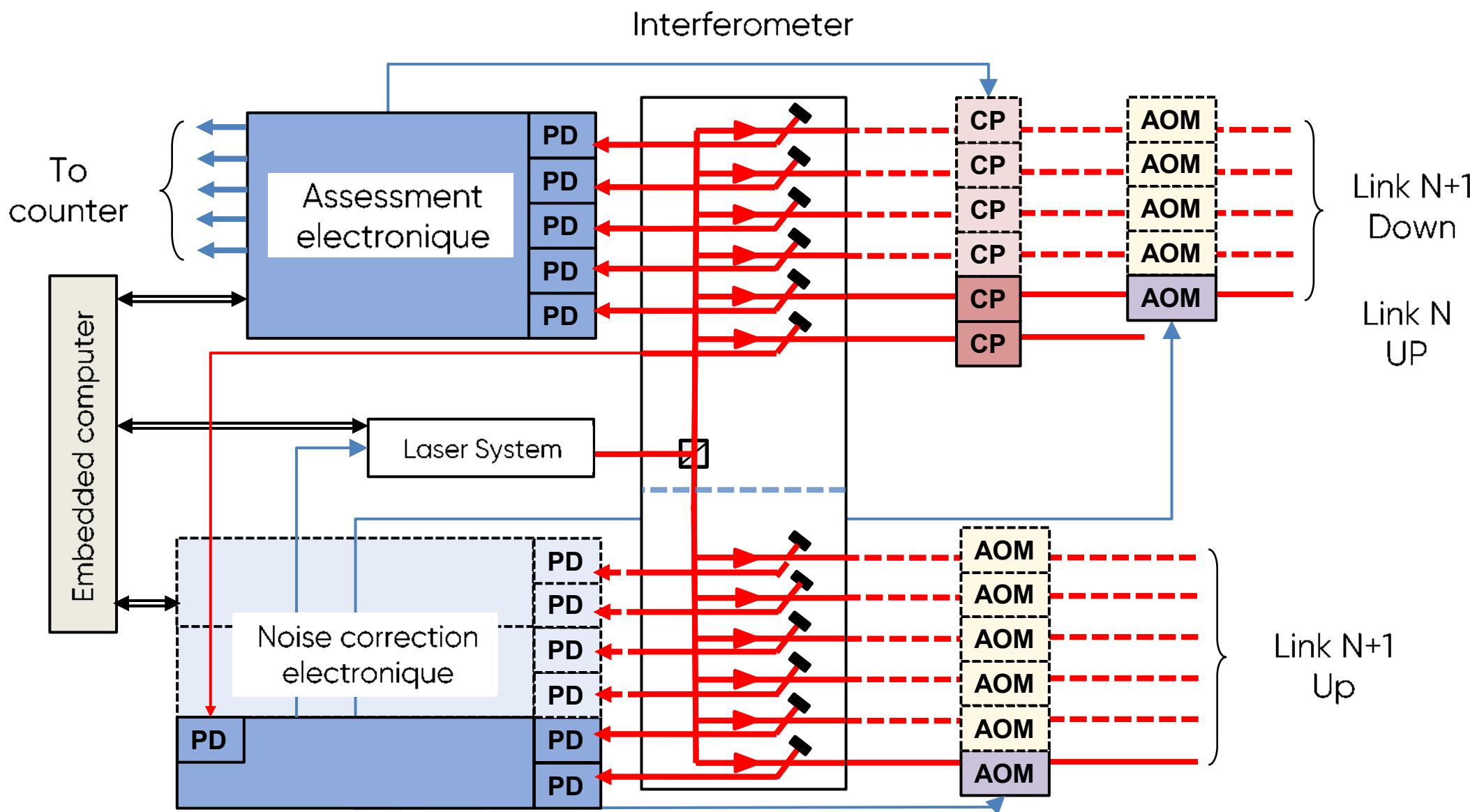
- 34 Repeatar Stations (without Ile de France)
- 36 Bidirectional Amplifiers (Keopsys)
- 4 User Modules (without Ile de France)



FUTUR OF EXAIL FIBER LINKS ACTIVITIES

Multi-branch Laser Station

- A « hub station » compatible with a multi-user network configuration (star topology)
- Link stability assessment

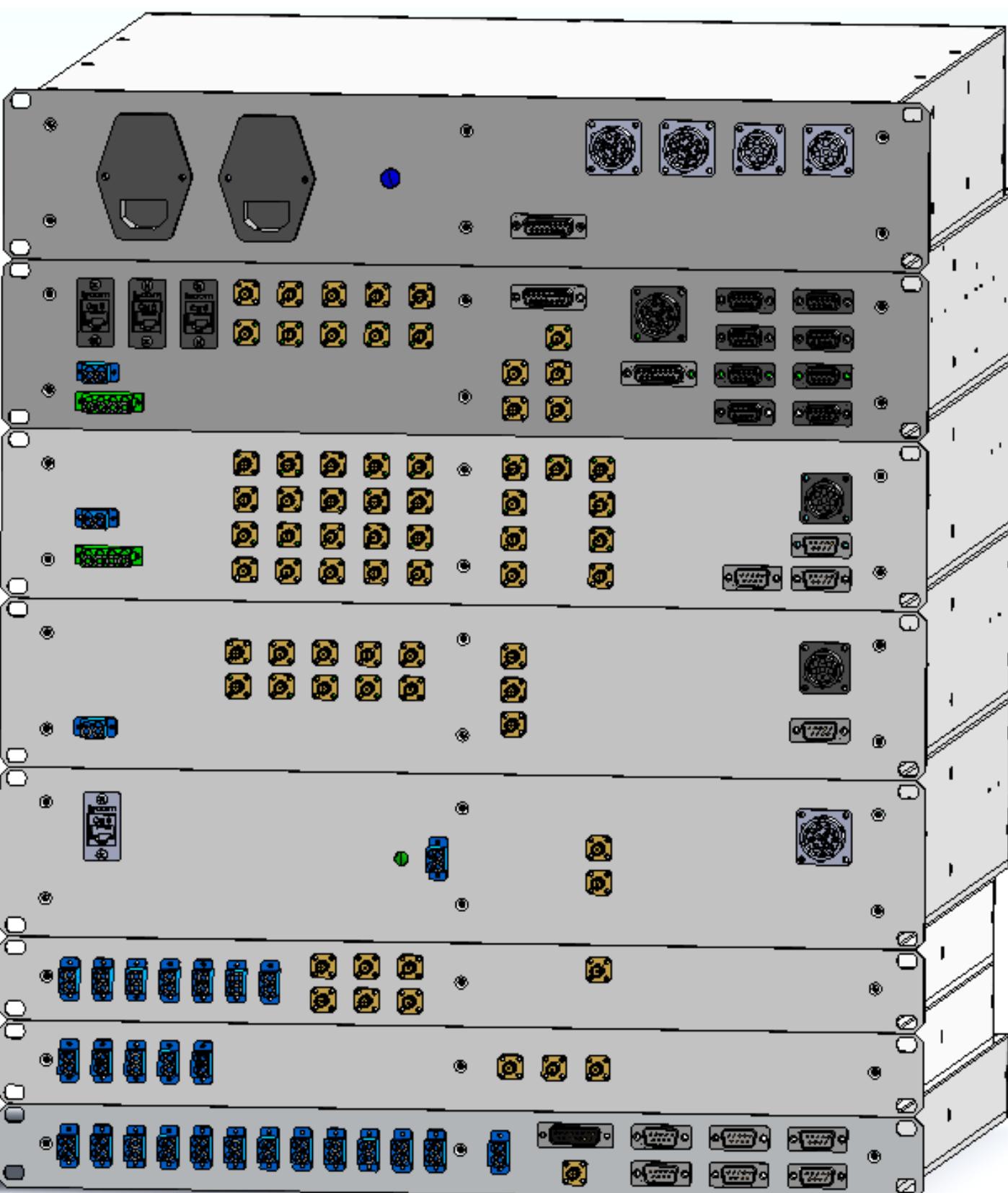


➤ Objectives

- Versatile
- Modular
- Compact
- Better performances than RLS

Features

- 13U height, 55cm depth, 19" lenght
- **12 phase-coherent optical output pairs** for simultaneous signal dissemination and stability assessment
- **Noise correction electronics** for up to 6 links with fully automated phase-lock loops
- **Stability assessment electronics** for up to 5 links with RF outputs compatible with commercial frequency counters
- Low-phase-noise laser system
- Compliant with DWDM Telecom network infrastructures
- **Intelligent and autonomous system** with remote control of all physical parameters



New technological bricks

➤ Free space interferometer

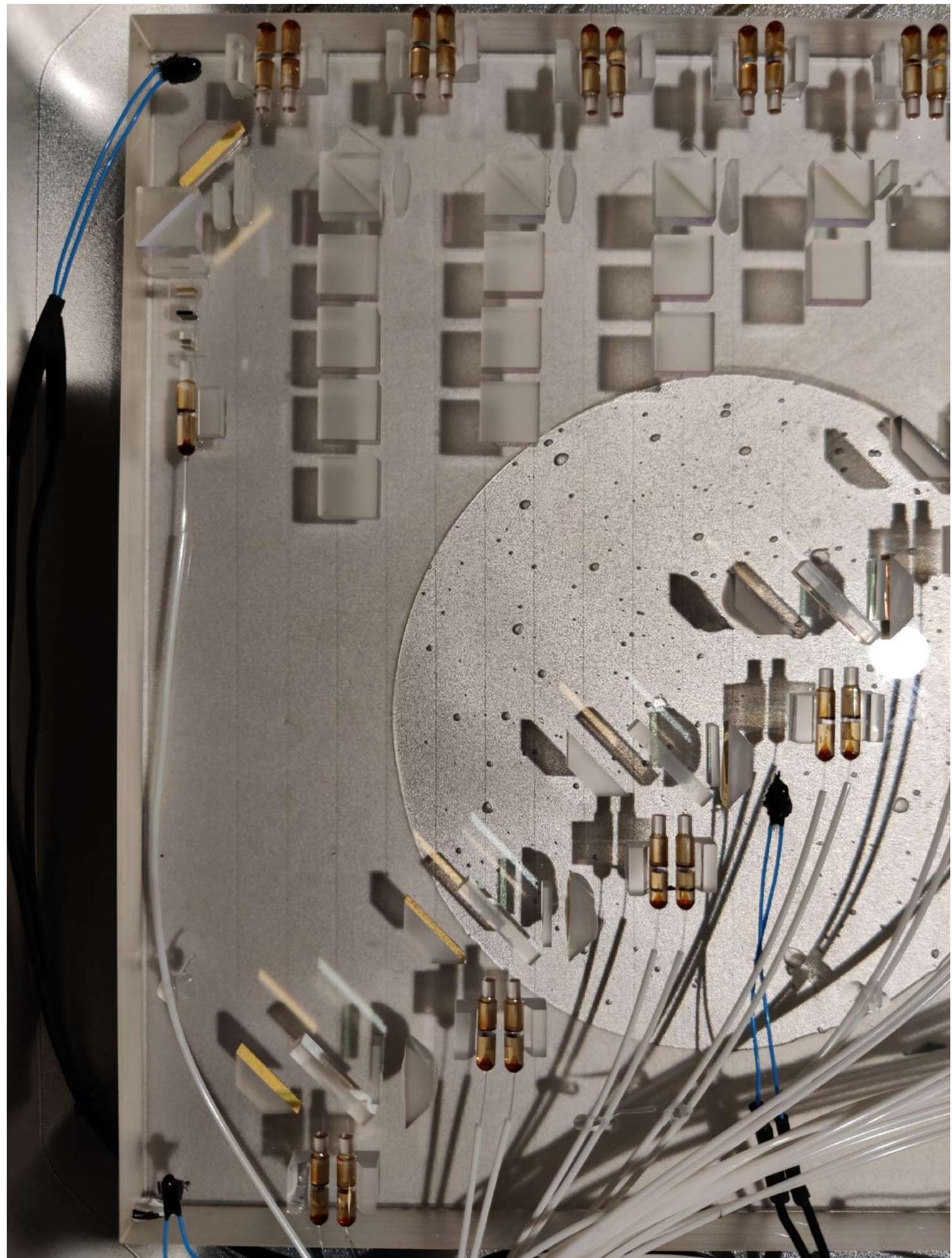
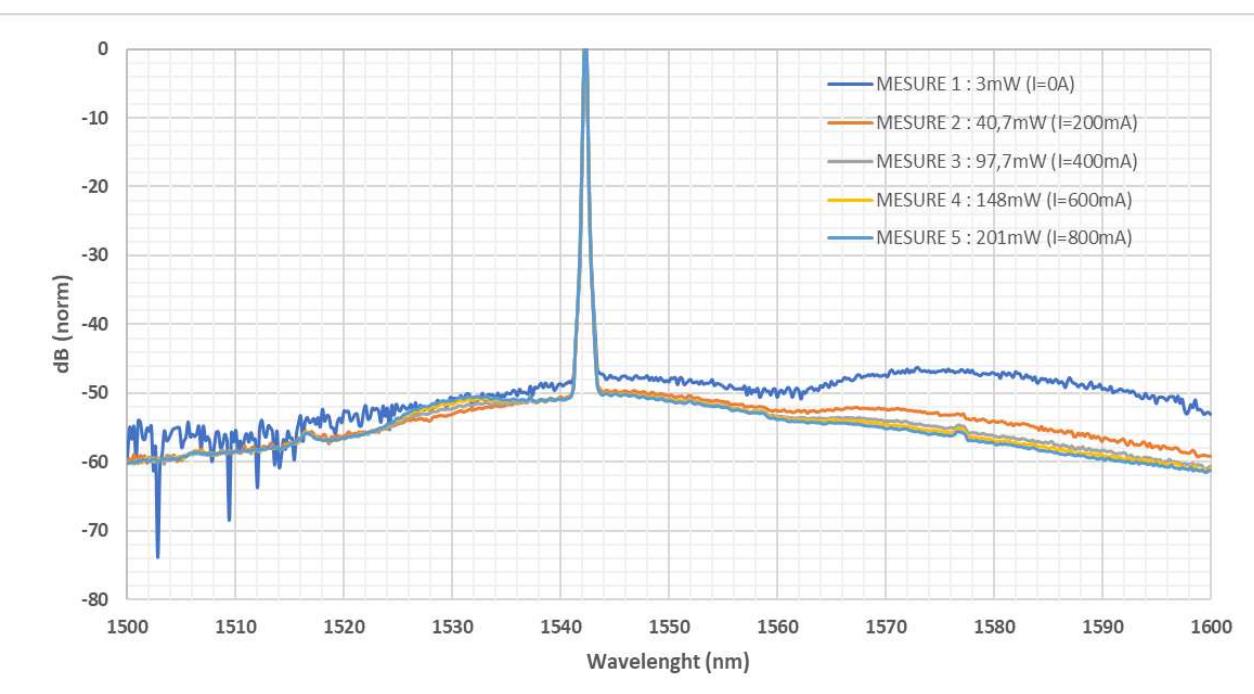
- Temperature sensitivity **< 0.1 fs/K** (RLS < 1 fs/K)
- Exail expertise (ex Kylia)

➤ End to End card

- Development of a new electronics cards
- Polarization control electronic restructuration

➤ EDFA

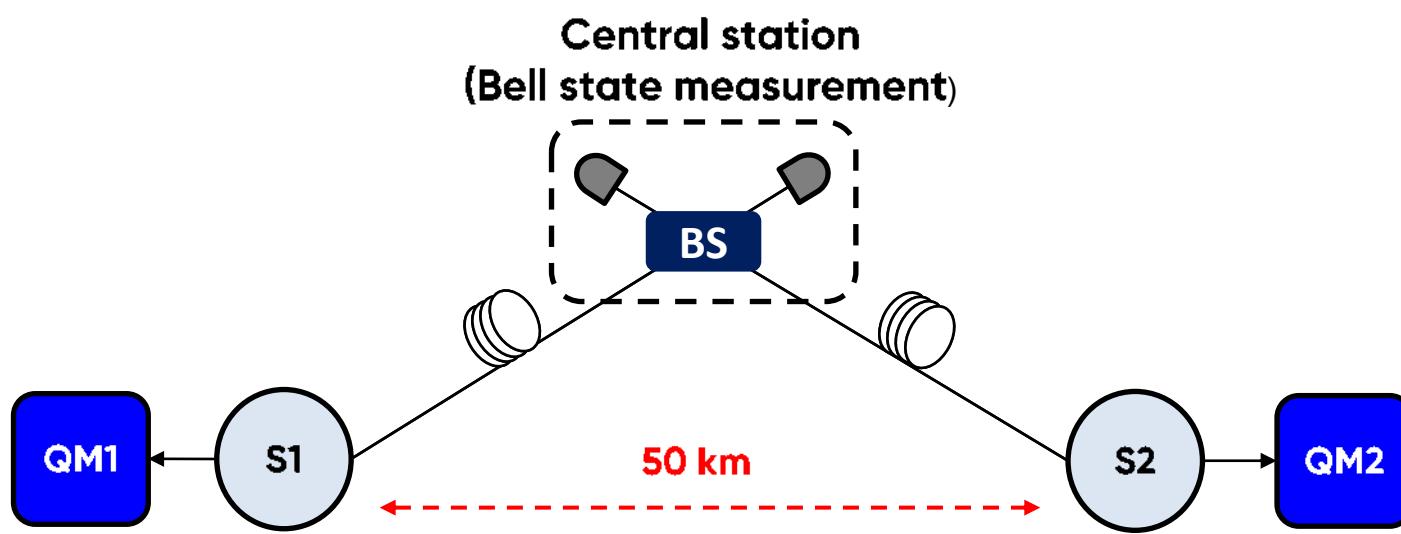
- Development of a single mode EDFA at 1542nm
- Exail expertise



International activities

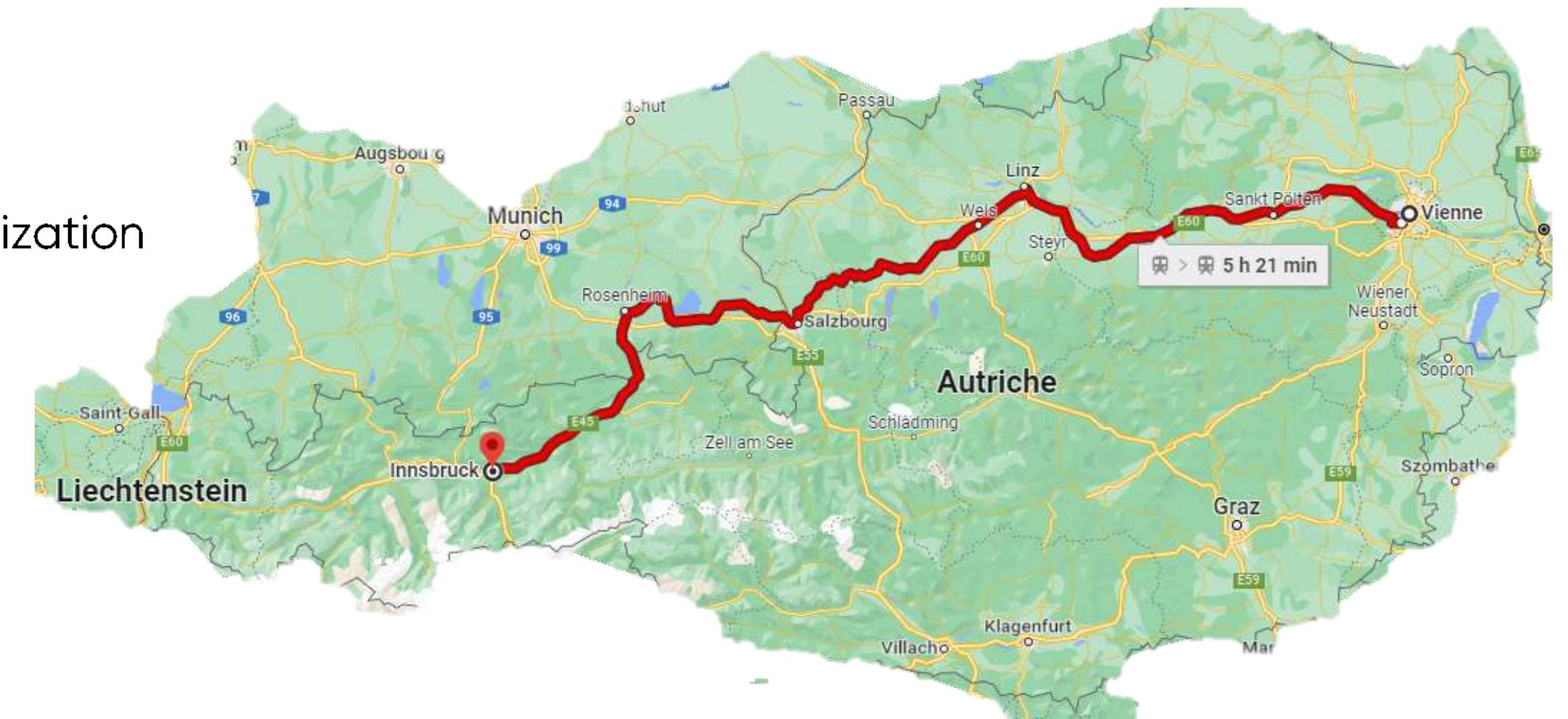
➤ Quantum Internet Alliance

- Collaboration with LKB and Weling
- Link stabilization for quantum memories entanglement



➤ Export

- 4 RLS and 1 MLS sold to NPL
- 5 RLS sold to Austria + help for installation and optimization
- More to come



Thank!

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