REFIMEVE+ project: a tool at hand for ultra-stable and accurate measurements

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Contents

I. EquipEx REFIMEVE+

- Collaboration with 20 laboratories
- Some scientific applications

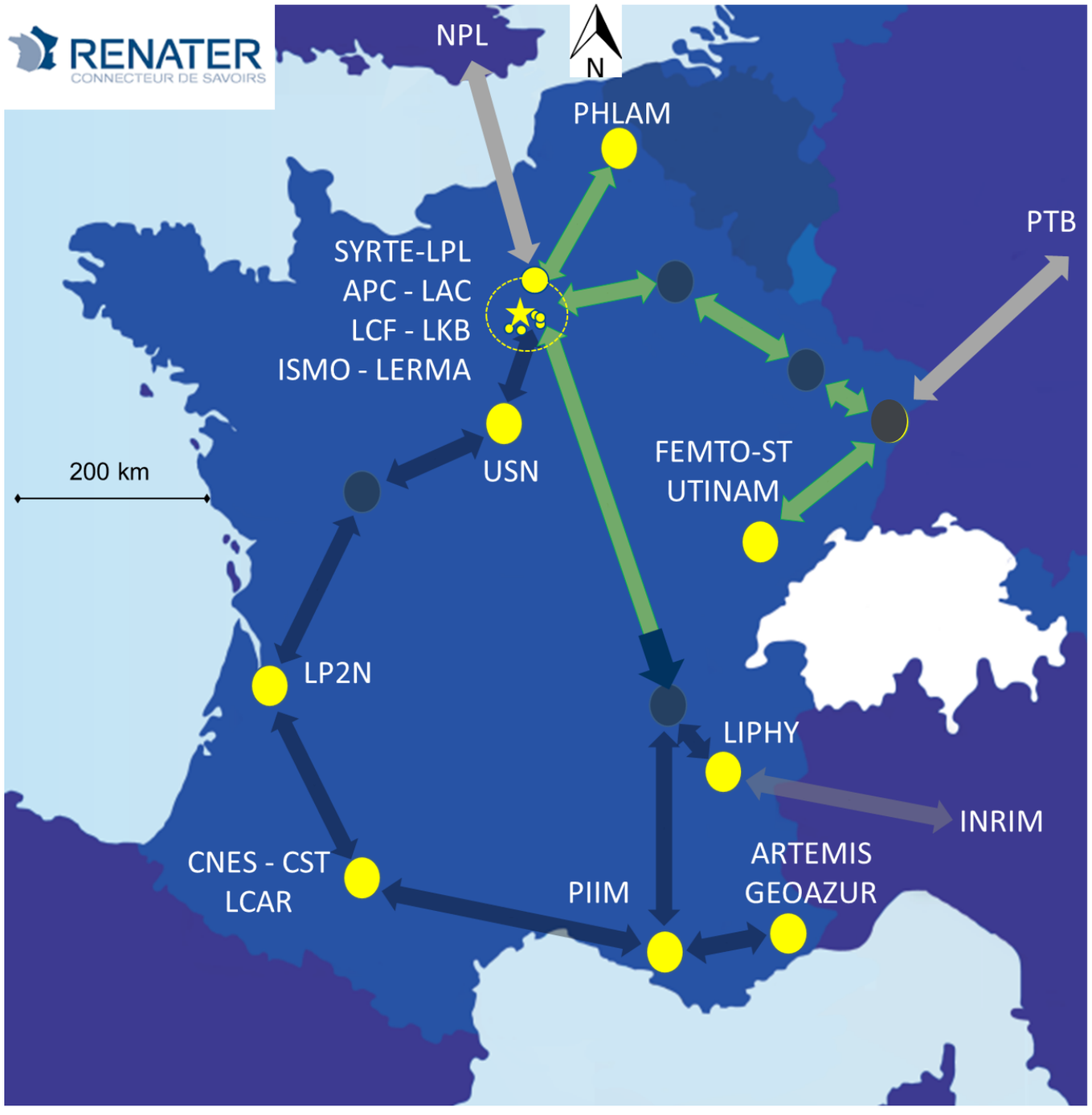
II. Construction of the network

- Frequency transfer with optical fibers
- Development of the network « core »

Conclusion and outlooks

REFIMEVE+ network

Metrological fiber network



- **Objective**: Distribution of an ultra-stable frequency reference (@1542nm) to academic laboratories for precision measurements

- 20 **partners laboratories** all over France

→ Metrological service to laboratories

- **Signal** of **stability** and **accuracy** at the level of the **best atomic clocks** of SYRTE
  - → Frequency stability and accuracy ~10^{-15}
  - → Traceable to UTC(OP)

- Network Architecture
  - → Collaboration with **RENATER**
  - Signal in parallel of data traffic = **fiber sharing**

- **Sustainability**
  - → Dedicated Fiber ≈ 200€ / km
  - → **Fiber sharing** ≈ cost / 10
  - \+ **Supervision** embedded in a Network Operation Center

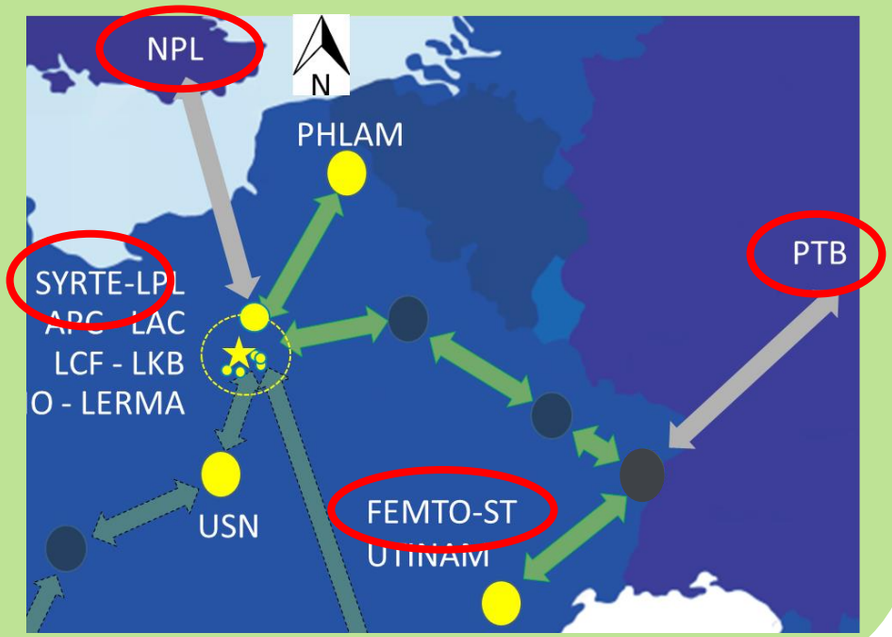
Examples of applications (1)

Clocks and cavities comparaison

SYRTE – PTB – NPL – FEMTO-ST

→ See Rodolphe Le Targat's talk

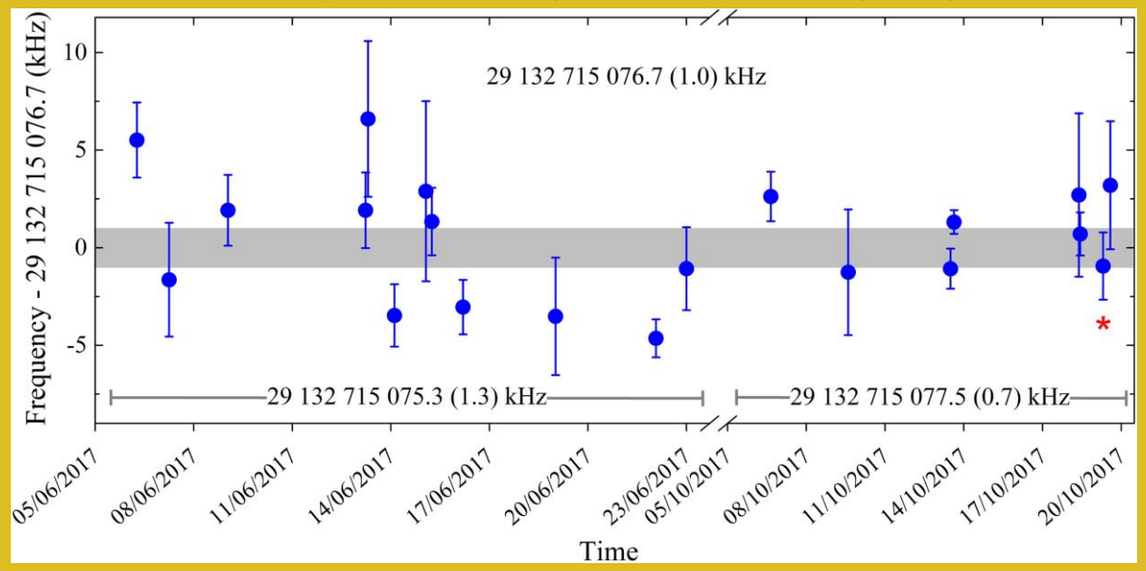
C. Lisdat and al. Nat. Com. *7*, 12443 (2016)



High Resolution Spectroscopy

Example of precision spectroscopy with methanol

R. Santagata and al. Optica, *6*, 411–423 (2019)

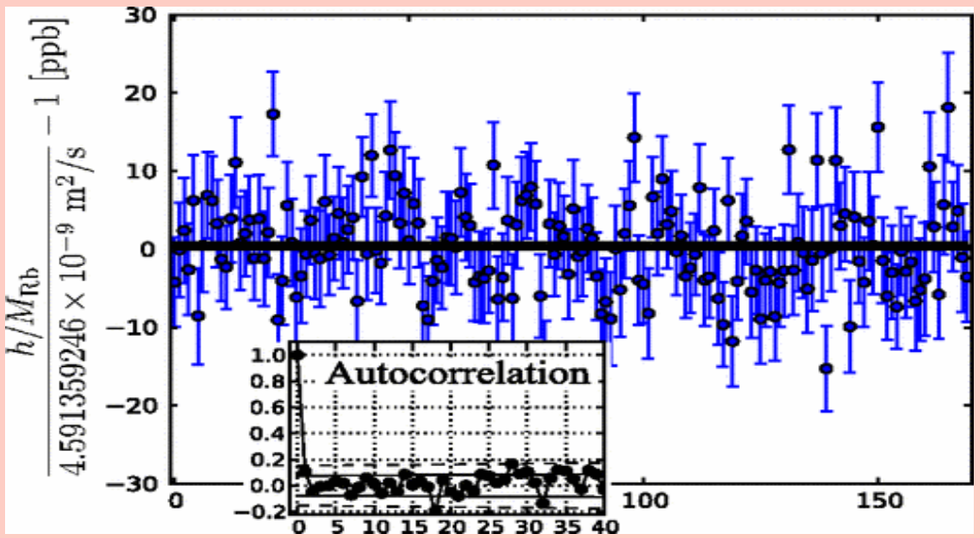


P(E,co,0,2,33) ro-vibrational methanol line

→ See Benoit Darquie's talk

Determination of h/m at LKB

→ See PRL 106, 080801 (2011)



Test of Lorentz invariance

$$\Delta_\alpha = \alpha c^{-2}[2\vec{w}\cdot(\vec{v}_A - \vec{v}_B) + (v_A^2 - v_B^2)] + \mathcal{O}(c^{-3})$$

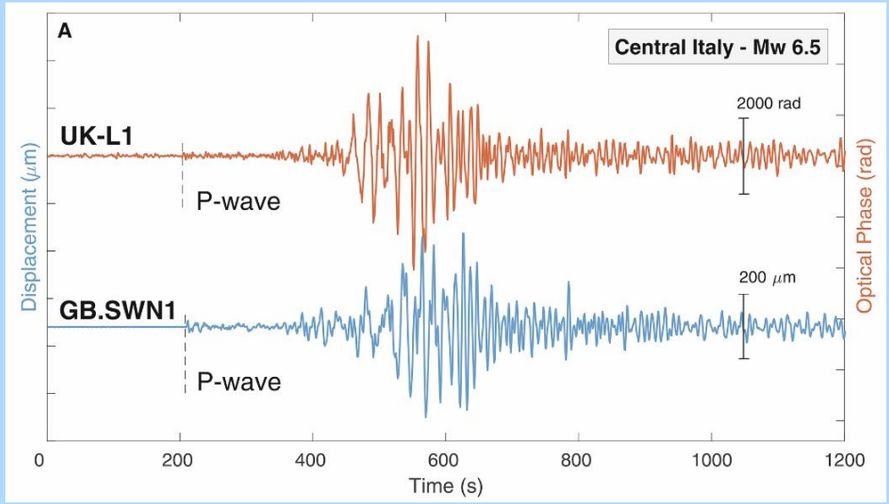
P. Delva et al., Phys. Rev. Lett., vol. 118, no. 22, (2017)

Examples of applications (2)

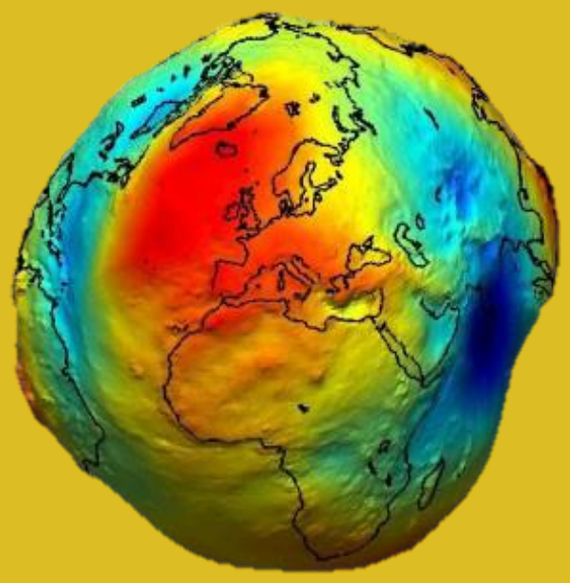
Seismic sensing

Central Italy earthquake – 30/10/2016

→ G. Marra et al., Science 10.1126/science.aat4458 (2018)



Chronometric geodesy



→ T. Takano *et al.*, *Nat. Phot.*, vol. 10, no. 10 (2016)

→ G. Lion et al., J Geod, vol. 91, no. 6, (2017)

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Frequency transfer through fiber links

- **Attenuation of the fiber**: 25-30dB for 100 km

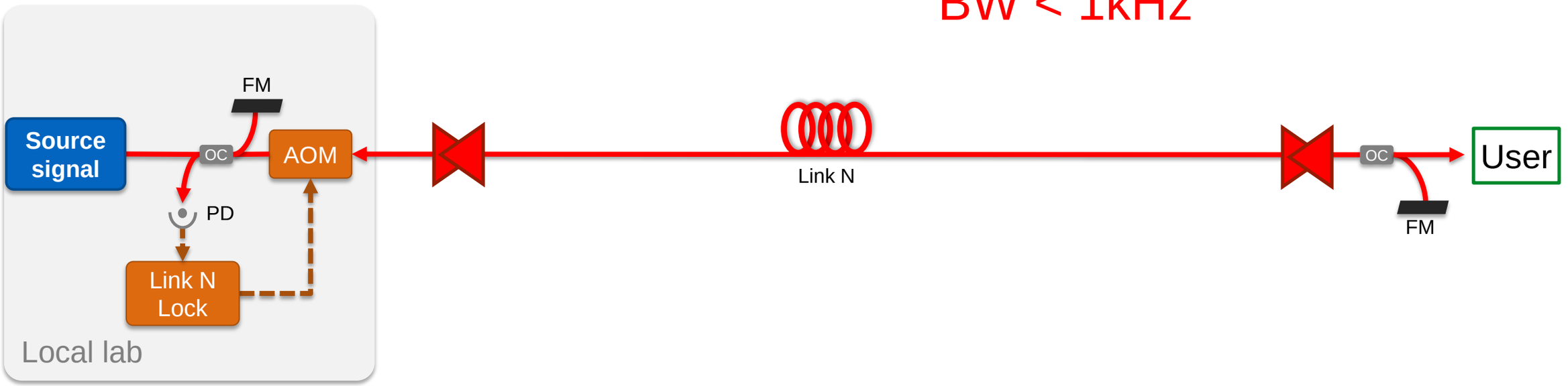
→ Bi-directional amplification EDFA

- **Accumulated noise**: it can vary for orders of magnitude depending on the fiber location (outside, burried, aerial,…)

→ Active Noise compensation→ Limited by propagation time

L > 50 km

BW < 1kHz



Frequency transfer through fiber links

- **Attenuation of the fiber**: 25-30dB for 100 km

→ Bi-directional amplification EDFA

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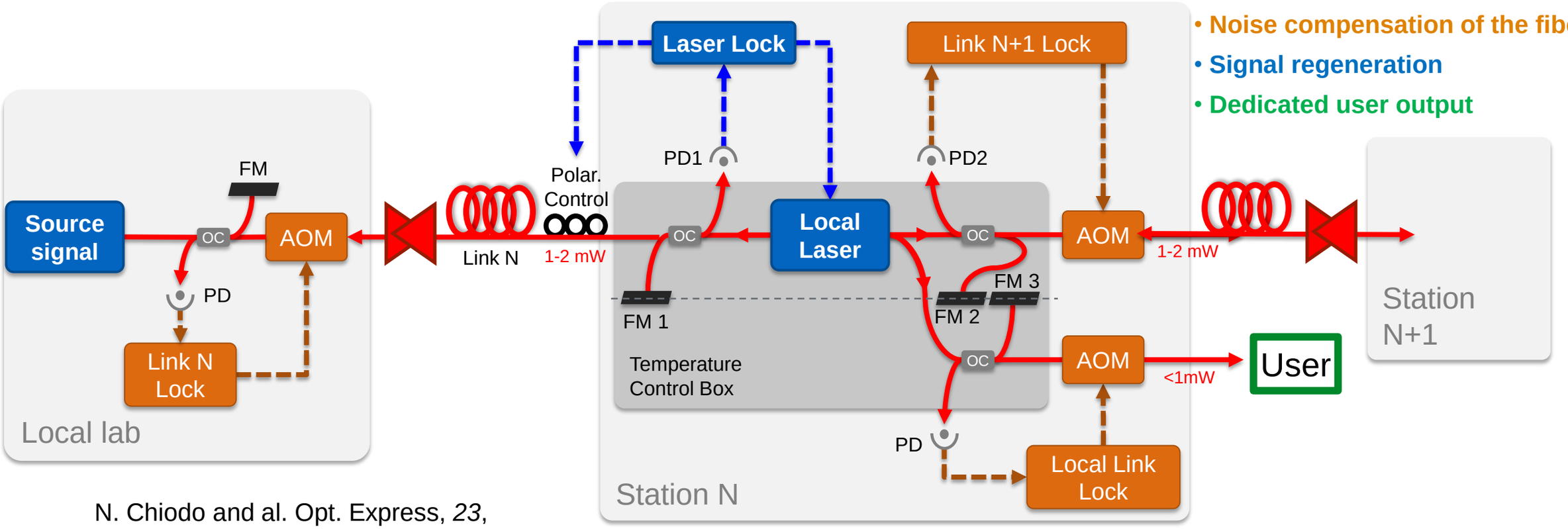
→ Active Noise compensation + Regeneration Laser Station



N. Chiodo and al. Opt. Express, *23*, 33927–33937 (2015)

→ Cascaded link with a remote station

First industrial-grade optical fiber link

applied optics

First industrial-grade coherent fiber link for optical frequency standard dissemination

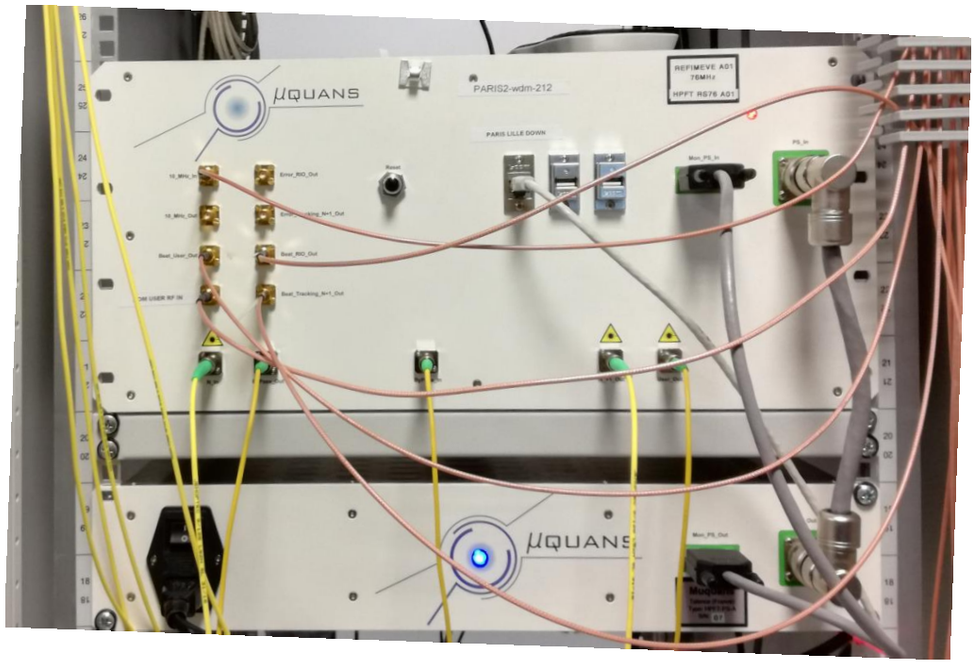
F. Guillou-Camargo,[1] V. Ménoret,[1] E. Cantin,[2,3] O. Lopez,[2] N. Quintin,[2,4] E. Camisard,[4] V. Salmon,[5] J.-M. Le Merdy,[5] G. Santarelli,[3,6] A. Amy-Klein,[2] P.-E. Pottie,[3] B. Desruelle,[1,*] and C. Chardonnet[2]

μQUANS

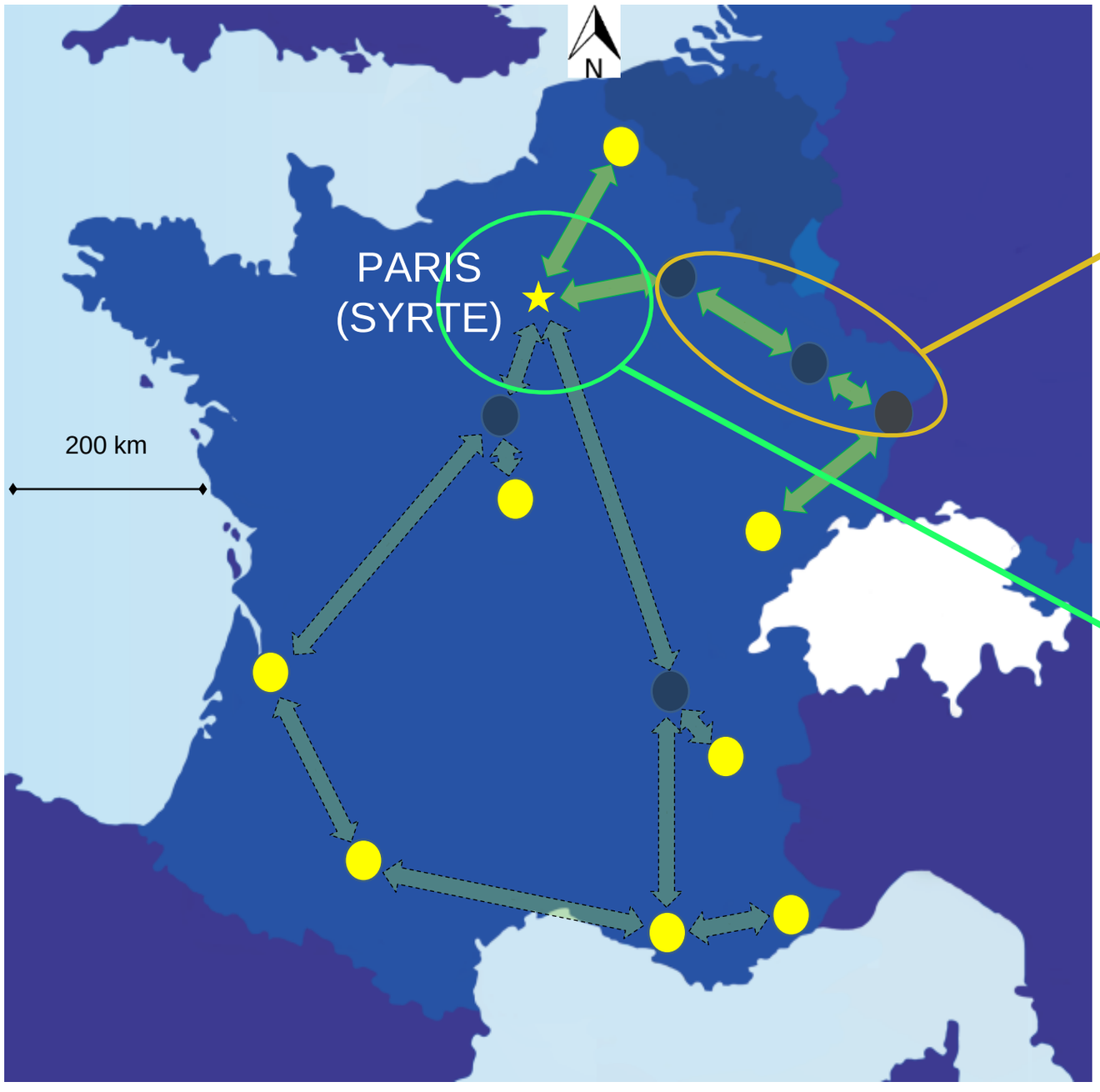
Construction, installation, operation, maintenance and supervision of the link

→**Uptime** of **99.5%** during 1 month (08/2018)

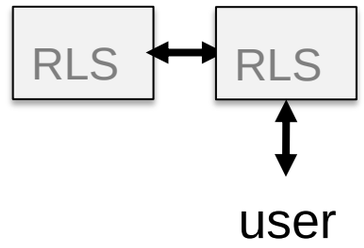
→**Stability** and **accuracy** at the state-of-the-art



The departure in Paris

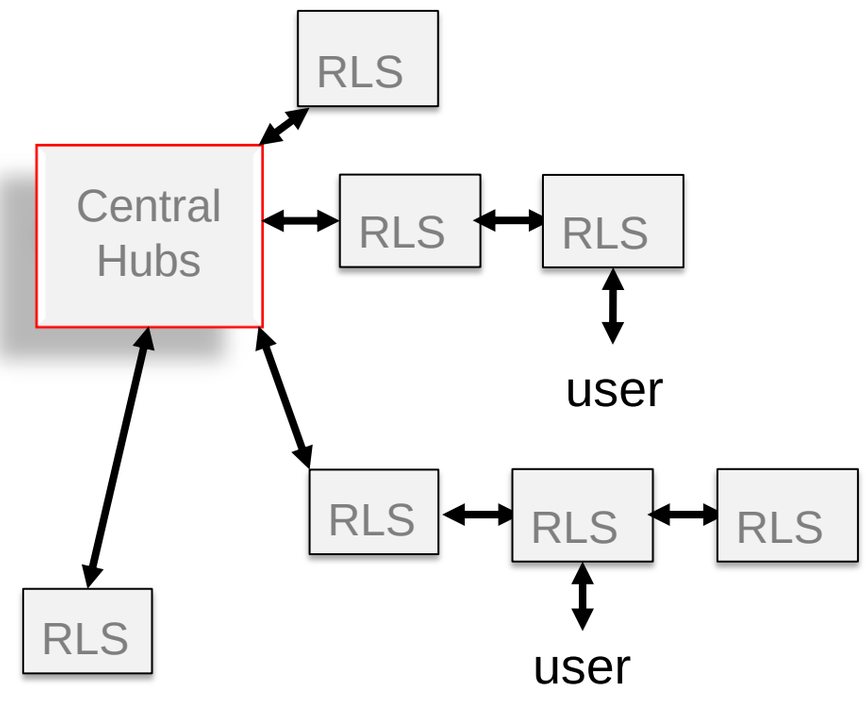


Point to point configuration

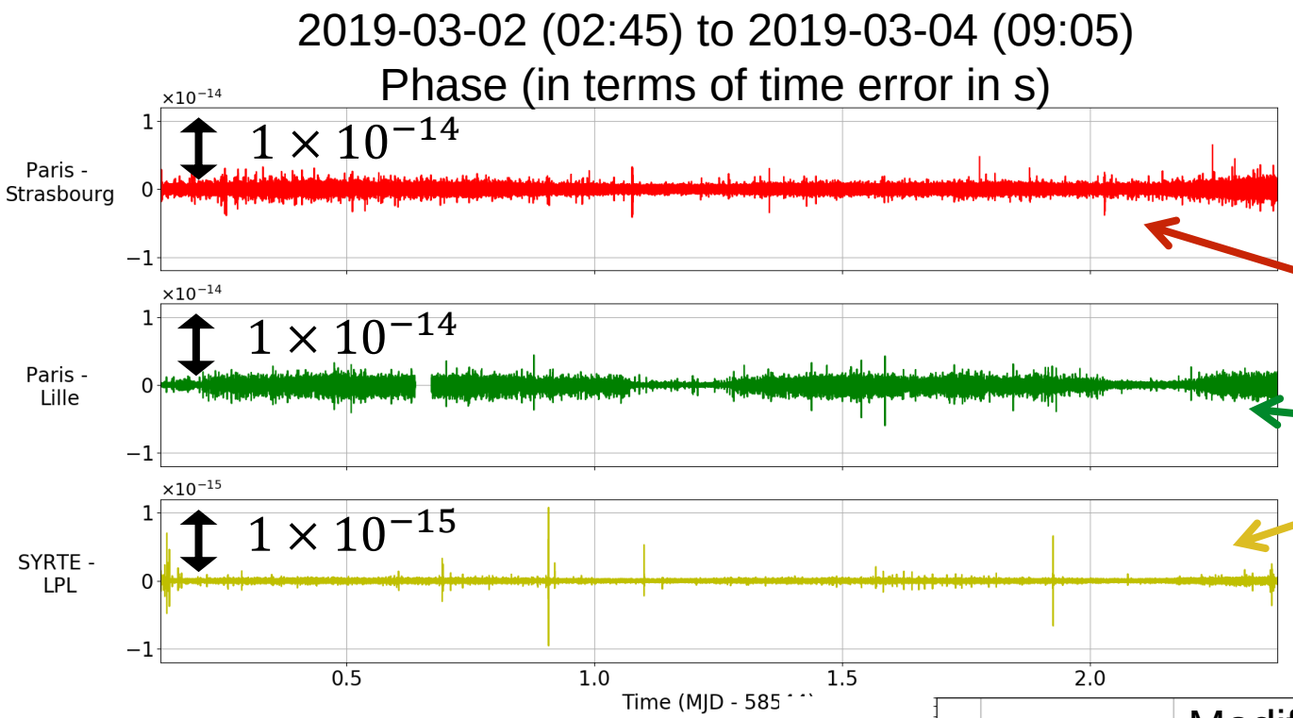


Central hub required
for a dissemination of more than 2 links/users

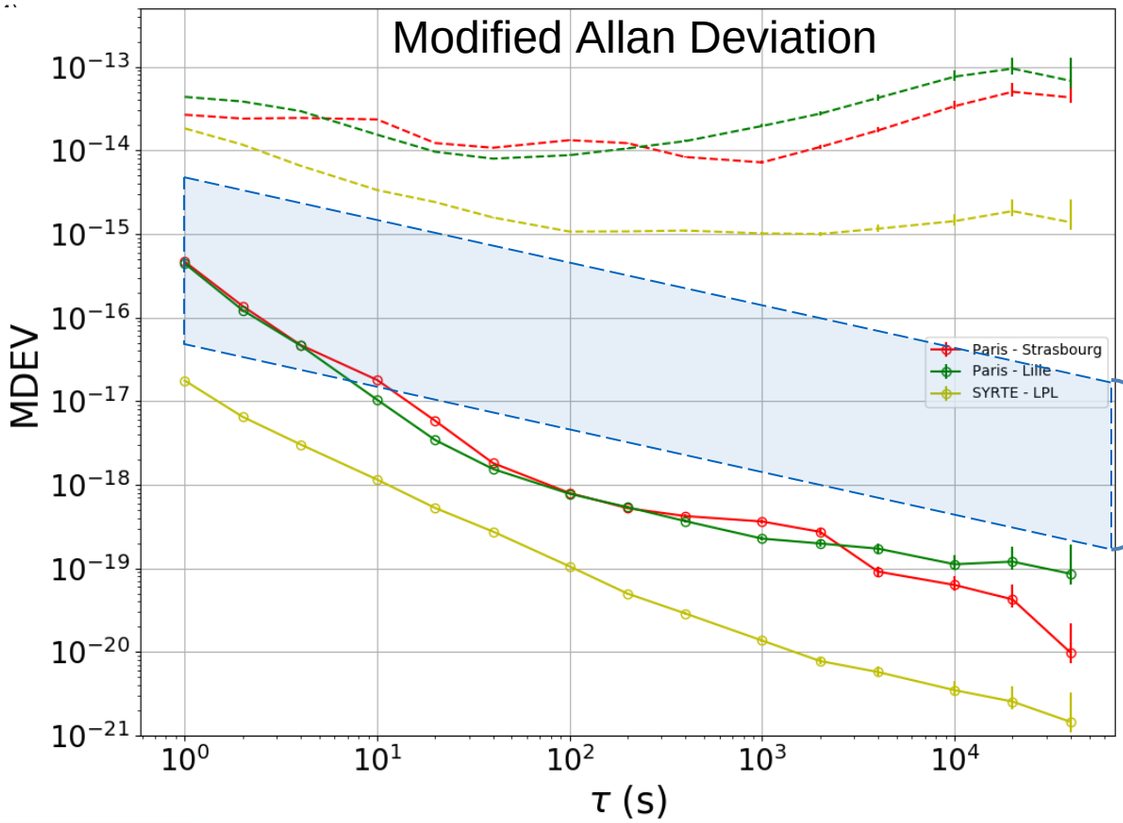
Hub configuration



Links stability and accuracy



	Distance (km)	Uptime (%)	Accuracy
Paris – Strasbourg	2×705	99.9	6.93×10^{-20}
Paris – Lille	2×340	99.4	4.25×10^{-20}
SYRTE – LPL	2×43	100	3.1×10^{-21}



Optical clocks

Conclusion

- **A metrological service for academic laboratories**

→ Applications in geophysics, spectroscopy, fundamental physics, metrology, precision measurements…

- **Reliable and sustainable network**

➢ **RENATER** & **industrial**-grade equipment

➢ "**Core**" of the network operationnal

➢ Deployment in progress