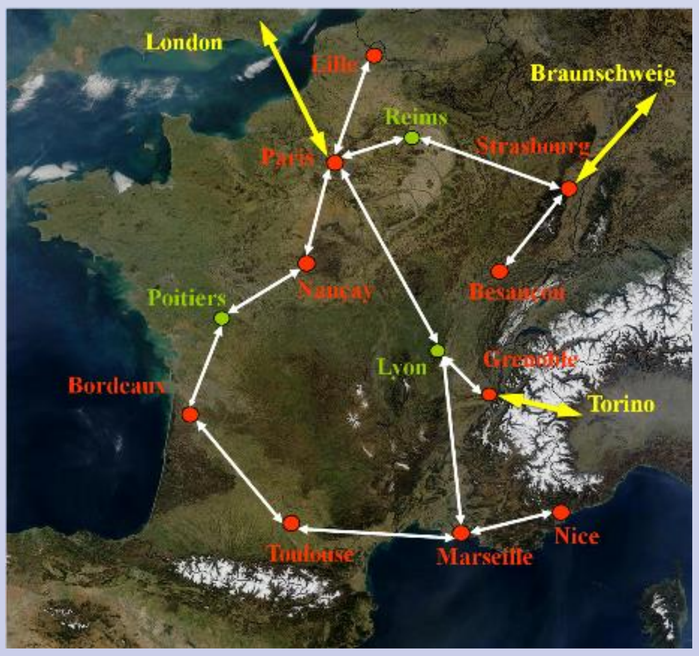
Towards a continental network for accurate and ultrastable frequency dissemination

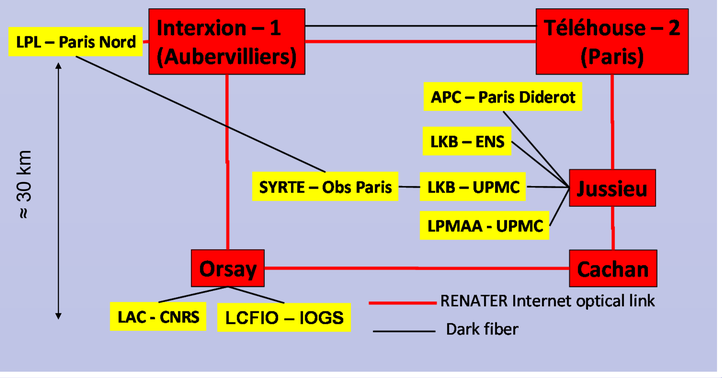
A. Bercy[1], B. Chanteau[1],O. Lopez[1], W. Zhang[2], Y. Le Coq[2], F. Auguste[1], B. Darquié[1], C. Chardonnet[1], A. Amy-Klein[1], and G. Santarelli[2,3]

1. Laboratoire de Physique des Lasers (LPL), CNRS/Université Paris 13, Villetaneuse
2. LNE-SYRTE, CNRS/LNE/Observatoire de Paris, Paris
3. Laboratoire Photonique, Numérique et Nanosciences (LP2N), CNRS/Institut d'Optique/ Université de Bordeaux I, Bordeaux

« Réseau Fibré Métrologique à Vocation Européenne » REFIMEVE+



- French REFIMEVE+ project funded
  - distribution of the best frequency references available at SYRTE to about 20 French labs
- DWDM (dense wavelength multiplexing) on the Internet backbone
  - Simultaneous transmission of the Internet data traffic and the ultrastable metrological signal on the same fiber but with different wavelengths
- Collaboration with French National Research and Education Network RENATER



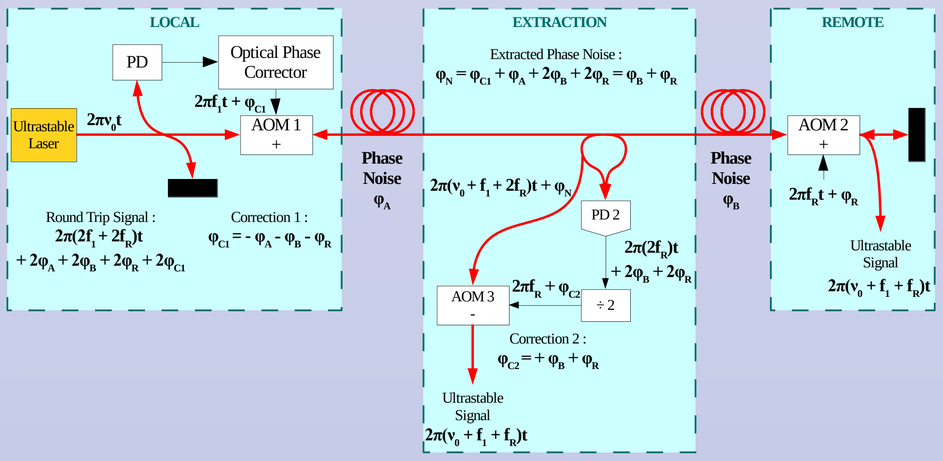
Motivations

Optical fiber links have brought the potential to transfer frequency with very high accuracy and stability thanks to an active compensation of the phase noise due to fluctuations of the optical length. An ultra accurate and stable frequency reference can be transferred over long distances using the very high frequency (~200 THz) of the optical carrier. The high sensitivity detection of the optical phase using heterodyne technics in conjunction with ultra stable lasers, are the basic tools to achieve low noise optical frequency transfer. In last five years several experiments in the USA, Europe and Japan have explored the limits of this method [1-5]. A key-question is the capability to extend ultra-stable frequency standard distribution to a larger scale and possibly to any users. In the last three years we have demonstrated an easily scalable technique since it is using commercial telecommunication fiber networks and is compatible with data traffic [6-7]. Switching from dedicated to a public fiber network is a major breakthrough for a possible generalization of the concept of optical fiber link frequency distribution. The outcome of such a technique leads to a wide distribution of a frequency reference on a national or continental scale. Two applications are presented below :

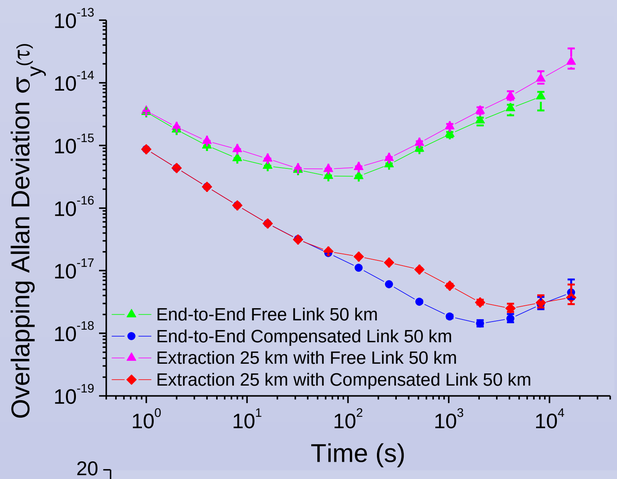
- Multipoint dissemination to several labs in the same metropolitan area [8]
- Stability transfer to mid-IR for ultra-high resolution molecular spectroscopy

Ultrastable on-line extraction

Experimental scheme

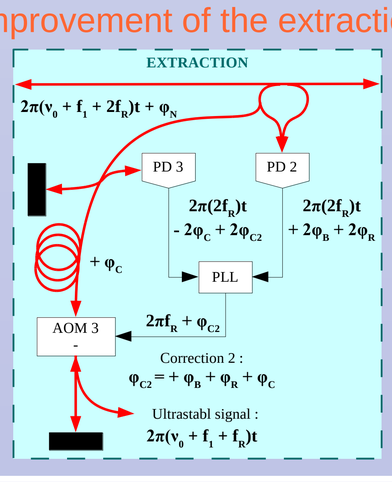


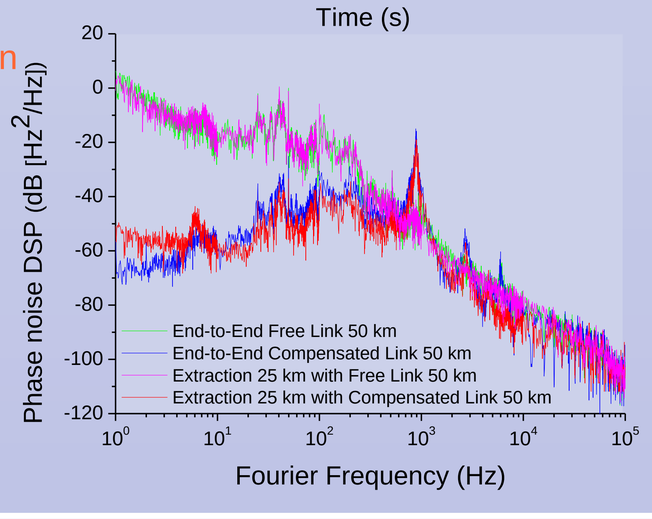
Frequency measurement results



The aim of this work is to address the issue of multipoint frequency dissemination. A point-to-point network needs a lot of fibers and is not the optimum solution. We developed an on-line extraction station as first proposed by G. Grosche [8]. First tests on fiber spools demonstrated that the noise compensation was working properly at the extraction end. Set-up will be improved to correct the thermal effects observed on sections of non-compensated fibers.

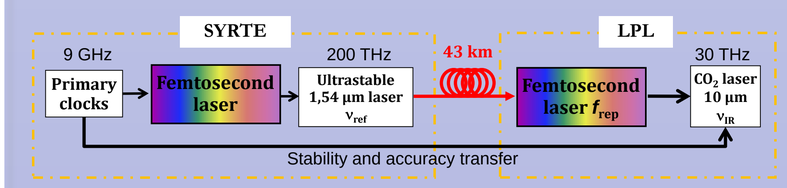
Improvement of the extraction





Accuracy and stability transfer in the mid-IR

The frequency reference signal transferred through the optical link is exploited to measure/control the frequency of a mid-IR laser, using a femtosecond laser as a tranfer oscillator. This opens the way to ultra-high-resolution spectroscopy and tests of fundamental physics with molecules (for instance the non conservation of parity [9] or the stability of m_e/m_p [10])



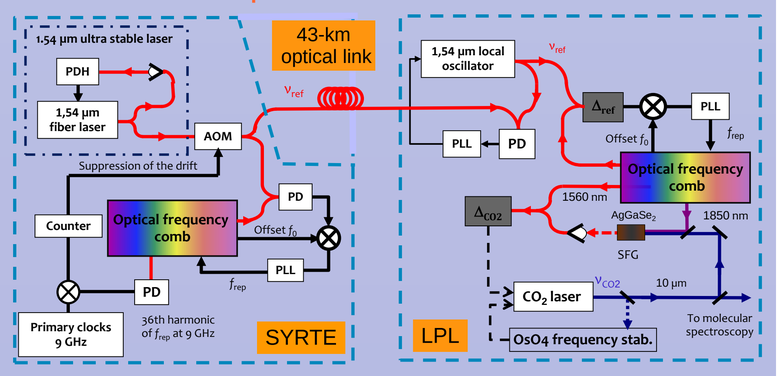
$$\nu_{ref} \approx N\, f_{rep}$$

$$\nu_{IR} \approx n\, f_{rep}$$

$$\nu_{IR} \approx \frac{n}{N}\nu_{ref}$$

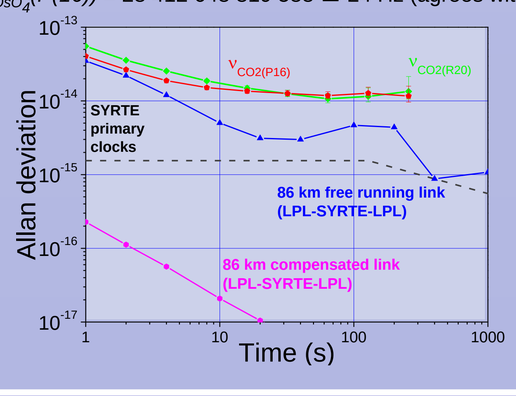
Mid-IR frequency measurement or control

Experimental scheme

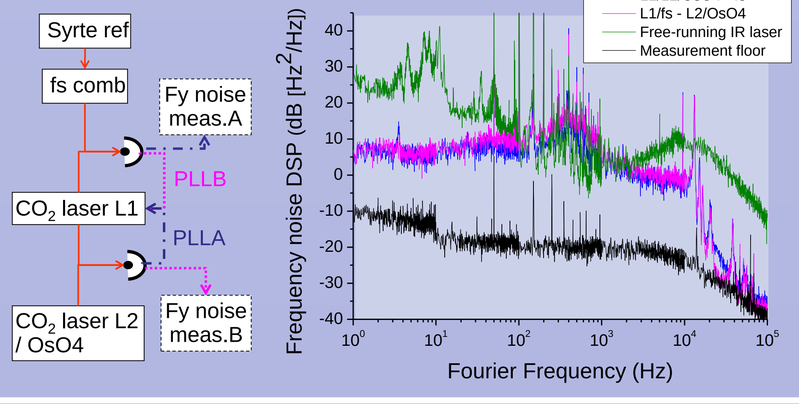


Frequency measurement results

$\nu_{CO_2/OsO_4}(P(16))$ = 28 412 648 819 588 ± 24 Hz (agrees with bibliography)



Mid-IR frequency stabilisation onto ν_{ref}



Outlook

- Signal distribution to several labs in Paris area
- Network development in Paris area and in France
- Optical link extension towards Germany and at the European scale

- Improvment of the extraction set-up
  - temperature stabilization
  - minimization of the non-reciprocal fiber paths
  - insertion of a compensated short link
  - insertion of a local laser locked to the extracted signal
- Demonstration of extraction on installed fiber network

- Extension of the mid-IR frequency stabilization to Quantum Cascade Lasers, using the frequency reference transferred through the optical link
- Application to high-resolution molecular spectroscopy, specifically a test of parity non conservation

References

[1] R. Newbury, P. A. Williams, W. C. Swann, Opt. Lett. 32, 3056 (2007).
[2] H. Jiang et al, J. Opt. Soc. Am. B 25, 2029 (2008).
[3] G. Grosche et al, Opt. Lett., 34, 2270 (2009).
[4] M. Fujieda et al, Opt. Express, 19, 16498, (2010).
[5] K. Predehl et al, Science, 336, 441 (2012).
[6] O. Lopez et al, Opt. Express 18, 16849 (2010).
[7] O. Lopez et al., Optics Express **20**, 23518 (2012)
[8] G. Grosche, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany; patent application DE 10.2008.062.139, "Method for making available a reference frequency" (personal communication, 2010).
[9] B. Darquié et al, Chirality, vol. 22, pp. 870-884 (2010)
[10] A. Shelkovnikov et al, Phys. Rev. Lett, 100, 50801 (2008).