LIFT: an optical fiber infrastructure for time & frequency dissemination in Italy

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THE LIFT PROJECT

LIFT (**I**talian **L**ink for **F**requency and **T**ime) is the future optical fiber network for Time and Frequency dissemination in Italy. LIFT is promoted by the Italian Institute of Metrology (INRIM), the Italian Institute of Nuclear Physics (INFN), the University of Firenze (UNIFI) and the Italian Institute of Astrophysics (INAF) and is funded by the Italian Ministry of Education and Research (MIUR).

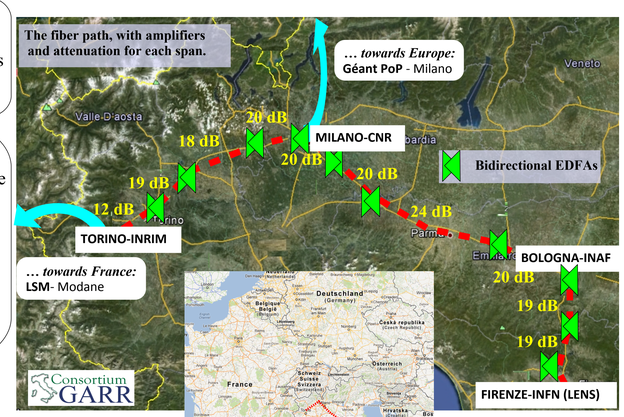
A first Torino-Firenze span is under realization by INRIM, UNIFI and Politecnico di Torino (PRIN project, funded by MIUR) and it is expected to be operative by the end of 2013, when a coherent fiber link for optical frequency transfer will enable remote frequency comparisons between the atomic clocks located at INRIM and at UNIFI laboratories.
By 2015, this backbone will be upgraded to the LIFT project providing dissemination to Milano and Bologna.

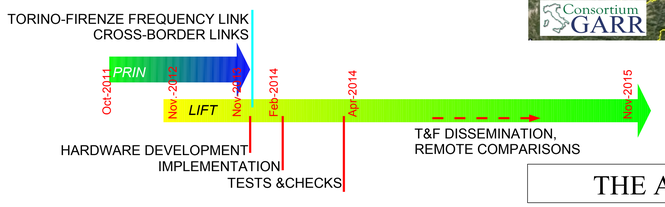
AIMS:
- Absolute frequency calibration for high resolution spectroscopy
- Remote comparisons of atomic clocks
- Remote clocks in replacement of local H-Masers
- Timebase distribution and synchronization at 100 ps level
- Create a distributed network for T&F services on national scale

KEY POINTS:
- Both **Time** and **Frequency** distribution on the same infrastructure
- Strong interaction between Research Centres and Industrial partners
- Different accuracy and stability grades for multiple partners needs
- Multiple user distribution

LIFT & NEAT-FT

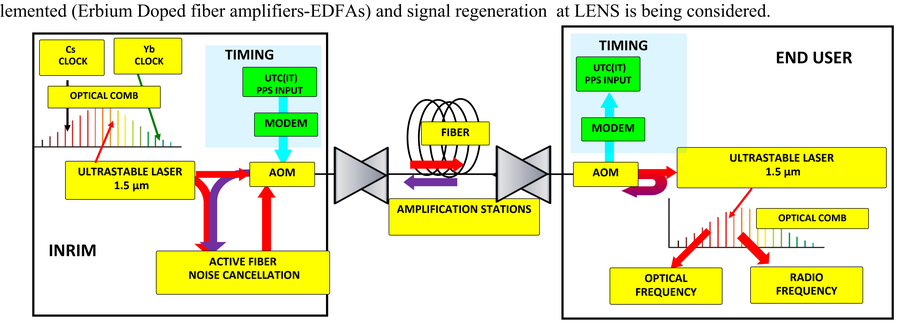
INRIM is partner of the consortium for the NEAT-FT project, and the LIFT project will be developed in tight relation with NEAT-FT.
LIFT will provide the connection of the Italian Network to a forthcoming European Network through the cross-borders:
-***Italy-Switzerland*** (feasible end 2013) via Milano, possibly in collaboration with Géant project.
-***Italy-France*** (feasible end 2013) via Frejus tunnel. Laboratoire Souterraine de Modane (LSM) will be one of the nodes.





THE ARCHITECTURE

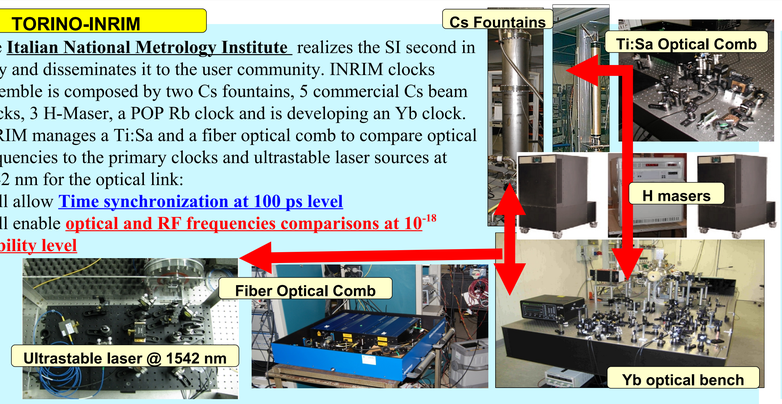
Ultrastable radiation at 1542 nm is generated at INRIM and measured against a primary standard through an optical fiber comb; then, it is sent to the end user via optical fiber. Here it can be converted to another optical or RF frequency through an optical fiber comb. For users interested in the time distribution, at INRIM a PPS signal will be encoded with pseudo-random modulation in the optical carrier, and will be decoded by the end user with a modem.
To obtain a stable transfer, the optical path has to be stabilized. This is accomplished by reflecting part of the radiation from the end user back to INRIM, where it is compared with the source light. This allows to detect the fiber noise and to cancel it through a Phase-Locking Loop, using an Acousto-Optic Modulator as actuator. Regarding Time dissemination, the delay variations will be read by the modem, and corrected down to 100 ps level.
The link will be realized with a dedicated dark fiber supplied by GARR, the Italian National Research and University Network. A couple of fibers, hired by INRIM, is used to setup two independent links (redundancy&check purpose). Overall length Torino-Firenze is 650 km, estimated attenuation is 194 dB (0.3 dB/km). At least 10 bidirectional optical amplification stations will be implemented (Erbium Doped fiber amplifiers-EDFAs) and signal regeneration at LENS is being considered.



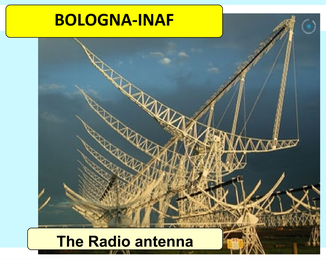
THE PARTNERS

TORINO-INRIM

The **Italian National Metrology Institute** realizes the SI second in Italy and disseminates it to the user community. INRIM clocks ensemble is composed by two Cs fountains, 5 commercial Cs beam clocks, 3 H-Maser, a POP Rb clock and is developing an Yb clock. INRIM manages a Ti:Sa and a fiber optical comb to compare optical frequencies to the primary clocks and ultrastable laser sources at 1542 nm for the optical link:
-will allow **Time synchronization at 100 ps level**
-will enable **optical and RF frequencies comparisons at 10^{-18} stability level**

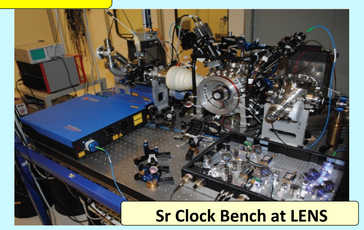


BOLOGNA-INAF



The **Medicina Observatory** hosts both a 32 meter dish for Very Long Baseline Interferometry (VLBI) and a 20'000 m^2 collecting area for Pulsar research:
-needs **accurate timing** for VLBI, now also in real time VLBI, by 1Gb/s fiber.
-needs **Frequency dissemination at 10^{-15} level** for Pulsar monitoring on long and very long time scales.
-offers **T&F** cross checks by direct comparisons with Pulsar and Quasar, now defining the best possible inertial frame of reference.

FIRENZE-UNIFI



The **European Laboratory for NonLinear Spectroscopy (LENS)** is involved in high resolution spectroscopy and in developing a ^{88}Sr optical clock:
-needs **optical frequency dissemination at the 10^{-18} level** to carry on absolute characterization of the Sr clock with respect to the SI second.

MILANO-CNR

Istituto di fotonica e nanotecnologie (IFN-CNR) is interested in **high grade frequency dissemination**

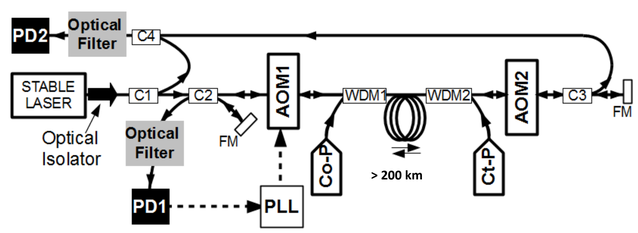
FIRENZE-INO

The **Italian Institute of Optics** is involved in high resolution molecular spectroscopy
-needs high grade **optical frequency dissemination**

RAMAN AMPLIFICATION

The optical link has two fibers at disposal. The first fiber will be equipped with EDFAs, whereas for the second Raman Optical Amplification will be used. This powerful tecnhique is a valid alternative to EDFA systems: it uses the fiber itself as a gain medium for amplification in both directions, ensuring full reciprocity, high gain (> 25 dB per pass) and robustness, thanks to a wide gain bandwidth.
Amplifier placement can be properly designed to obtain **very long spans (> 200 km)**, reducing the number of amplification stages, the costs and increasing the reliability of the infrastructure.
Raman Amplifiers have been tested at INRIM and allowed coherent transfer of the optical carrier on **60 dB optical losses in a single span,** obtained with 200 km of fiber spools and an additional 16 dB attenuator, equivalent to more than 250 km of fiber. Obtained stability is on the right graph.
In our experiment, the gain was limited by the maximum power available with our pump, and the gain of 32 dB that we obtained with a double-pump scheme is in principle achievable with a 1 W single counter-propagating pump.

[see C. Clivati et al., arXiv:1211.3910]



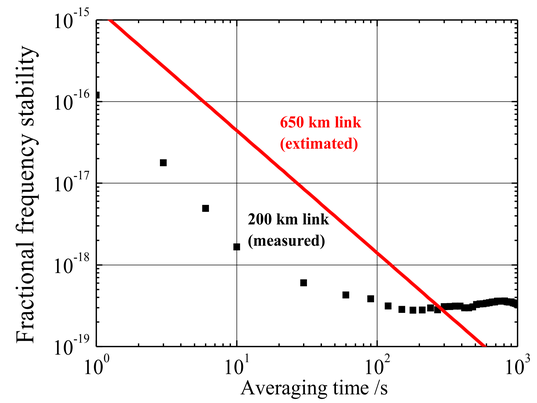
C=optical couplers; FM=Faraday Mirrors; WDM=pump couplers.
Photodiode PD1 detects the fiber noise. A Phase Locked Loop (PLL) crrects it using AOM1 as actuator. AOM2 is used as frequency shifter.
Transferred radiation is measured on PD2.

Co-P: co-propagating Raman pump (260 mW diode laser providing 9 dB gain)
Ct-P: counter-propagating Raman pump (800 mW fiber laser providing 23 dB gain)

PhD theses &PostDoc positions available

RESULTS & OUTLOOKS

We tested our fiber noise compensation system on 200 km of fiber spools inside our laboratory and on a 47 km fiber loop located in the urban area around Torino. The urban network is implemented on a Dense Wavelength Division Multiplexing architecture and the ITU channel 44 was dedicated to the link experiment to evaluate fiber noise.
On the basis of this measurement we could exstimate the expected stability of the Torino-Firenze link. The graph reports the stability of the 200 km compensated link in the laboratory (obtained using Raman Optical Amplification) and the extimation of the 650 km link stability, based on the phase noise measured on the installed 47 km fiber and on the well-proved assumption that stability scales as $L^{3/2}$, where L is the link lenght.



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