
Publishable JRP Summary Report for JRP SIB02 NEAT-FT

Accurate time/frequency comparison and dissemination through optical telecommunication networks

Background

The aim of the project NEAT-FT is to investigate new techniques for phase-coherent comparison of remotely located optical clocks, separated by distances of up to 1500 km using optical fibre links. Within the scope of the JRP the equipment necessary for reliable operation of fibre links will be developed and all technological steps towards a full optical link infrastructure demonstrated. Beside frequency dissemination, new techniques for time transfer over optical fibre networks will be investigated in order to provide better timing signals than currently available with GPS receivers. For typical spans up to 100 km the JRP aims to improve the accuracy down to about 100 ps. Furthermore, the feasibility of a European fibre network connecting optical clocks in Europe will be studied in close collaboration with potential fibre providers.

Leading European National Metrology Institutes (NMI) and one representative (CESNET) from the National Research and Educational Networks (NREN) have joined to meet the scientific and technical needs for highly stable and accurate reference signals in fundamental physics, GNSS, geodesy, astronomy, and (space-) industry.

Need for the project

The best optical clocks today reach a fractional accuracy of the order of 10^{-17} and this outstanding performance makes them ideal tools for various tests of fundamental physics. Moreover, optical clocks have now surpassed the best caesium-based atomic clocks in both accuracy and stability and are the most promising candidates for the expected redefinition of the SI unit of time, the second. However, adequate means to compare distant clocks at the highest level of accuracy are missing. Comparison is a vital issue for optical clocks development and to explore their fundamental limitations. However, as conventional satellite-based techniques do not reach the required performance alternatives must be developed.

There is an increasing demand by scientific organisations and universities for accurate links to NMIs for reference to the SI second. In typical research laboratories, high-resolution optical frequency measurement is limited by the accuracy of commonly-used rubidium clocks, which are referenced to UTC via GPS. In the longer term, it is likely that some of the most advanced applications of future atomic clocks will be space based, and their operation will require ground stations with access to ultra stable frequency references linked to the best available ground clocks. In this respect optical fibre links to such locations will become of central importance. Furthermore, those sites will allow linking the network to other continental networks (USA, Asia, Australia) using relay satellites and optical free space techniques that are being developed today.

Scientific and technical objectives

The JRP addresses the following scientific and technical objectives:

- In WP1 and WP2 novel techniques for frequency comparisons in the $\sim 10^{-18}$ range at 1 day measurement time using optical fibres and the necessary equipment such as repeater stations, amplification concepts and remote control systems will be developed.
- “The development of methods, protocols and techniques for accurate time dissemination” and “the consideration of different complementary methods and levels of accuracy reaching from a sub-1 ns level to the sub- μ s level” will be carried out in WP3 and WP4.
- “Applications that require or significantly benefit from remote fibre links” will be identified and considered in WP5 in close collaboration with the stakeholders with the aim to foster the decision of funding a future European fibre network or of bi-directional connections of selected points of presence.

Report Status: CO Confidential, only for members of the JRP-Consortium (including EURAMET and the Commission Services)

Latest News, Results and potential impact

- REG AGH has successfully started in November 2012. With the REG from Akademia Gornicz-Hutnicza im. Stanislaw Staszica w Krakowie (AGH), Poland, one of the leading institutes in time and frequency in Europe outside the NMI community supports NEAT-FT. First joint measurements have been performed using the existing fiber link between PTB in Braunschweig and Leibniz University (LUH) in Hanover. AGH's novel technique for delay stabilization could be tested and evaluated. Stable operation of the full system over weeks has been achieved.
- REG UoS (University of Southampton) started in May 2013. The second REG now becomes active and joined the project.
- Meetings with the advisory board members in line with JRP meetings resulted in vivid discussions on future applications:
 - Investigating the possibility of fiber links between remote VLBI stations such as ONSALA (Sweden) and Metsähovi (Finland) VLBI stations was proposed by the advisory board.
- The Italian project LIFT for establishing an optical network for time and frequency has started in November 2012. LIFT will connect INRIM in Torino with LENS in Firenze via Milano and the Radio-astronomical Center in Bologna and has as a guaranteed lifetime of 3 years. First light was launched from Torino to Firenze and received in Torino by May 2013. Due to a limited number of amplifiers currently being available only one fiber link is established so far. Lighting of the second fiber is expected by the end of 2013.
- In November 2012 a workshop for stakeholders interested in advanced T&F transfer was organized in Hoofddorp, The Netherlands. For the workshop 85 participants signed up. Support of NEAT-FT was confirmed from GÉANT and DANTE representatives at the workshop. DANTE initiated an open call for applications requiring a fiber testbed. Five fiber routes between major GÉANT PoPs, including Paris – London, will be made available for scientific use by October 2013. Members of NEAT-FT have submitted two proposals in order to get access to the fiber route London-Paris and Vienna-Milano. In July we have been invited to negotiate the co-funding of the ICOF project.
- In May 2013 PTB has signed a contract with the fiber provider GasLine that allows establishing a direct fiber link (yellow route) between Braunschweig and Paris via a cross border link of RENATER and DFN in Kehl, and to extend this link towards MPQ (blue line). This will allow for future clock comparisons at the highest level of accuracy. Together with the activities and links mentioned above this is another breakthrough towards a European scientific network.



Figure 1: Topology of LIFT, the Italian fiber link project.

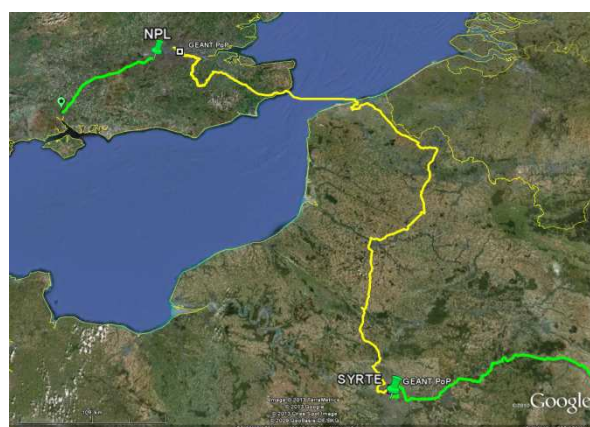


Figure 2: Envisaged fiber route from Paris to London (ICOF) via GÉANT (yellow).



Figure 3: Novel fiber link between OBSPARIS and PTB. This link (yellow) will allow clock comparisons at the highest level.

The results of the JRP will enable NMIs to perform better clock comparisons within Europe, and to disseminate highly accurate and stable frequency and timing signals to the user community for groundbreaking science and innovation. Some members of the potential user community are already included in the list of collaborating institutes.

Further information is available at our homepage: http://www.ptb.de/emrp/neatft_publications.html.

JRP start date and duration:	June 2012, 36 month
JRP-Coordinator: Dr. Harald Schnatz, PTB, Tel: ++49 531 592-4300 E-mail: Harald.Schnatz@PTB.de JRP website address: http://www.ptb.de/emrp/neatft_home.html	
JRP-Partners: JRP-Partner 1 PTB, Germany JRP-Partner 2 BEV/PTP, Austria JRP-Partner 3 INRIM, Italy JRP-Partner 4 MIKES, Finland JRP-Partner 5 NPL, UK	JRP-Partner 6 OBSPARIS, France JRP-Partner 7 SP, Sweden JRP-Partner 8 UFE, Czech Republic JRP-Partner 9 VSL, Netherlands JRP-Partner 10 CESNET, Czech Republic
REG-Researcher 1 (associated Home Organisation):	Radan Slavík UoS, United Kingdom
REG-Researcher 2 (associated Home Organisation):	Łukasz Śliwczyński AHG, Poland

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