Digital Implementation of a Two-Way Coherent Phase Transfer over Optical Fiber for Remote Clocks comparisons

Claudio E. Calosso[1], Elio Bertacco[1], Davide Calonico[1], Cecilia Clivati[1], Giovanni A. Costanzo[1,2], Matteo Frittelli[1], Filippo Levi[1], Alberto Mura[1], Aldo Godone[1]

[1]Divisione Ottica, Istituto Nazionale di Ricerca Metrologica, Torino, Italy
[2]Dipartimento Elettronica e Telecomunicazioni, Politecnico di Torino, Torino, Italy

Email: c.calosso@inrim.it

Frequency links over phase-stabilized optical fibers are now a well-established technique to perform remote frequency comparisons[1]. The fiber phase noise is typically compensated with a Doppler-cancellation scheme, in which the light travels twice in the fiber. This is the main limitation to the maximum achievable length.

Here, we present an alternative approach[2] based on a Two-Way phase transfer. With this technique the light travels only once in the link, hence it is affected by half-phase noise and by half the amplifiers noise, and the optical power and Signal to Noise Ratio at the two link ends are higher with respect to a Doppler-stabilized link. In this manner the maximum fiber haul can be significantly increased.

In this scheme, two frequency signals travel over an optical fiber in opposite directions and are synchronously phase-recorded at the two ends by means of tracking DDSs[3]. The link phase noise is cancelled by subtracting the two data-sets in post-processing.

We tested this scheme on a 47 km multiplexed fiber loop. Fig. 1 shows the phase noise of each signal, of their difference and the theoretical limit. This scheme enabled a remote frequency comparison at 4×10^{-21} at 10^4 s.

At the conference, we propose a detailed description of the technique and of requirements in terms of measures synchronization; particular attention will be devoted to the digital implementation that demonstrated to be very useful in this context.

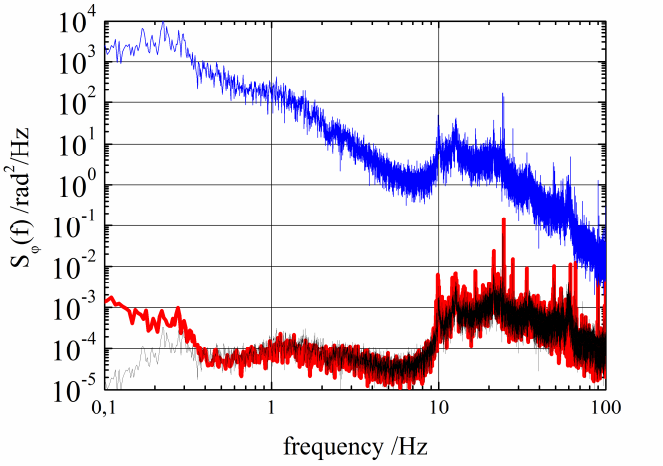

Fig. 1: The phase noise on each of the single lasers after traveling the link (blue line), and on their difference (red line). The black line shows the expected limitation due to non-symmetrical fiber length variations.

[1] A. Matveev et al. "Precision Measurement of the Hydrogen 1S- 2S Frequency via a 920-km Fiber Link," Phys. Rev. Lett., vol. 110, p. 230801-5, 2013.

[2] C. E. Calosso, E. Bertacco, D. Calonico, C. Clivati, G. A. Costanzo, M. Frittelli, F. Levi, A. Mura, A. Godone, "Frequency transfer via a two-way optical phase comparison on a multiplexed fiber network," Opt. Lett., vol. 39, (2014).

[3] C. E. Calosso, "Tracking DDSs in time and frequency metrology," Proc. of the Joint UFFC, EFTF and PFM Symposium (2013).