

# Optical Frequency Transfer with a 1284 km Coherent Fiber Link

D. Calonico<sup>1</sup>, E. K. Bertacco<sup>1</sup>, C. Calosso<sup>1</sup>, C. Clivati<sup>1</sup>, G. A. Costanzo<sup>2</sup>, A. Godone<sup>1</sup>, M. Frittelli<sup>1</sup>, A. Mura<sup>1</sup>, N. Poli<sup>3</sup>, D. V. Sutyurin<sup>3</sup>, G. M. Tino<sup>3</sup>, M. Zucco<sup>1</sup> and F. Levi<sup>1</sup>

<sup>1</sup>Istituto Nazionale di Ricerca Metrologica INRIM, Turin, IT

<sup>2</sup>Politecnico di Torino, Turin, IT,

<sup>3</sup>Università di Firenze, LENS and INFN, Sesto Fiorentino (FI), Italy

Email: [d.calonico@inrim.it](mailto:d.calonico@inrim.it)

We describe a coherent optical fiber link in Italy<sup>123</sup> for the dissemination of a high accuracy frequency reference, devoted to metrology, radio-astronomy and precision atomic physics.

First, we implemented a 642 km link that connects the Italian metrological institute (INRIM) with the University of Florence-European Nonlinear Spectroscopy Laboratory (LENS). This is the backbone of the project LIFT (Italian Link for Time and Frequency), aiming to link Italian scientific poles in Milan, Bologna and Florence, and to connect Italy to other European institutes. Second, we doubled the link to 1284 km: after reaching LENS, the signal comes back at INRIM, so that both ends are in the same laboratory and a direct characterization is possible. We demonstrate a technique based on the double roundtrip for noise cancellation on a single fiber, hence, the arming of a second fiber is avoided, that is beneficial to long hauls realizations. The resolution of the 1284 km link attains  $3 \times 10^{-19}$  in 1000 s, the frequency transfer accuracy is  $5 \times 10^{-19}$ .

At the conference, the link and, the characterization will be presented, together with the perspectives in the frame of European projects.

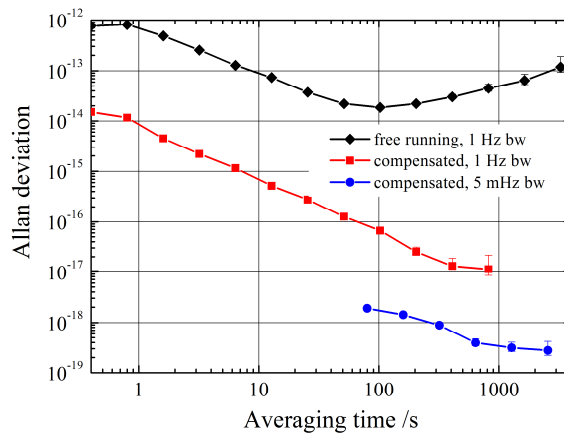


Figure 1. Allan deviation of the 1284 km optical link in open (diamonds) and closed loop operation, with 1 Hz (squares) and 5 mHz (circles) measurement bandwidth.

<sup>1</sup> O. Lopez, et al., “Cascaded multiplexed optical link on a telecommunication network for frequency dissemination,” Opt. Express 18, 16849-16857, 2010

<sup>2</sup> OS. Droste, et al., “Optical-Frequency Transfer over a Single-Span 1840 km Fiber Link”, Phys. Rev. Lett. 111, 110801, 2013

<sup>3</sup> F. Levi et al., “LIFT-the Italian Link for Time and Frequency” Proceedings of 2013 IEEE—UFFC joint symposia, Prague 2013