# High-resolution optical frequency dissemination on a telecommunication network

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***Abstract*—We transferred the frequency of an ultrastable laser over a 108-km-long urban fiber link comprising 22 km of an optical communication network fiber simultaneously carrying Internet data traffic. The metrological signal and the digital data signal were transferred over two different frequency channels in a dense wavelength-division multiplexing scheme. The metrological signal was inserted in and extracted from the communication network using bidirectional off-the-shelf optical add-drop multiplexers. The link-induced phase noise was measured and canceled with a round-trip technique using an all-fiber-based interferometer. The compensated link showed an Allan deviation of a few $10^{-16}$ at one second and below $10^{-19}$ at 10,000 s This work paves the way to a wide dissemination of ultrastable optical clock signals between distant laboratories via the Internet network.**

The transfer of ultra-stable frequencies between distant laboratories is a fundamental issue for a wide range of high-sensitivity experiments in advanced metrology and fundamental physics, as for example test of the fundamental constants stability. Optical clocks are indeed expected to reach instability level of $10^{-17}$ or better at one day measurement time, with the recent development of single ion traps and cold atoms. Since a few years, the transmission of frequency standards over optical fiber has been investigated. Compared to satellite link, fiber link are easier to implement and can potentially provide better performance. To take fully advantage of the optical fiber media the direct optical frequency transfer is the appropriate choice. Since 2007, several experiments of optical frequency transfer over a fiber link of more than 100 km were reported [1-5].

We transferred the frequency of an ultra-stable laser over 108 km of urban telecommunication fiber. The link is composed of 86 km [4] dedicated dark fiber and 22 km fiber from the French Scientific network RENATER, where optical signals from the internet traffic are co propagating with the stabilize laser light but at different wavelength. The stable optical signal is inserted or extracted in the RENATER fiber

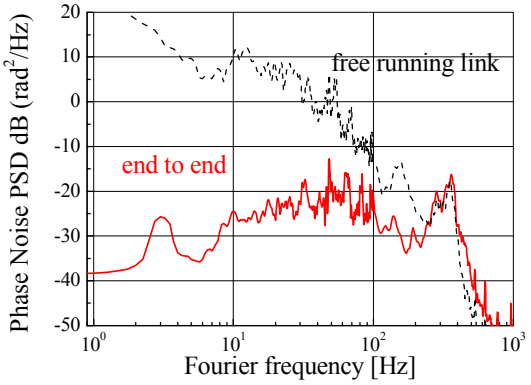


Figure. 1. Phase noise power spectral density of the compensated (red solid trace) and free-running link (black dash trace)

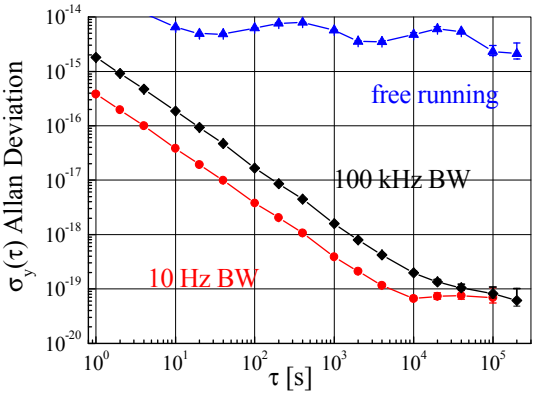


Figure. 2. Allan deviation of the compensated 108 km link with 100 kHz measurement bandwidth (black trace) and 10 Hz measurement bandwidth (red trace) and free-running 108 km link (blue trace)

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with low insertion losses optical add-drop optical multiplexers. The fiber-induced phase noise is displayed on Figure 1. It is measured and cancelled with the classical round-trip technique using an all fiber-based interferometer. The compensated link shows an Allan deviation of a few $10^{-16}$ at one second and a few $10^{-19}$ at 10000 seconds (Fig. 2). This opens the way to a wide dissemination of ultra stable optical clocks signals between distant laboratories via the Internet optical fiber network infrastructure [6].

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