Improved Optical Clocks Comparison via standard DWDM optical network

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The possibility of using standard (i.e. not specially modified) DWDM infrastructure for optical clocks comparison is based on a so-called alien wavelength service, when a dedicated wavelength channel in the network is devoted for propagating metrological signals. In this situation, however, the symmetry of bidirectional signals exchange is broken, as the truly bidirectional scheme is substituted with two unidirectional parallel optical paths, consisting of two fibers (in the same cable) and separate sets of network amplifiers. Therefore the stability achieved in optical frequency distribution using DWDM networks, that has been reported till now, is rather insufficient, being in the range of 1^{-16} to 10^{-15} (for 1000 s and longer observation)[1].

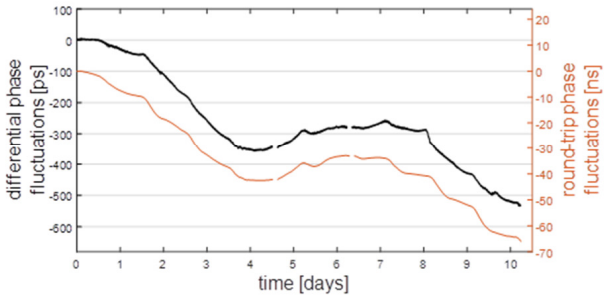

Fig. 1: Correlation between differential and round trip phase fluctuations, observed in 1500 km-long DWDM link.

The reason for the abovementioned stability degradation is related to differential phase fluctuations in the two parallel fibers, which are not compensated, differently to the round-trip phase fluctuations, which are efficiently compensated using a standard phase stabilization setup. As we however observed, the differential phase fluctuations are strongly correlated to round-trip ones (see Fig. 1), and this correlation may be used for improving clocks comparison accuracy by means of proposed measurement data post-processing.

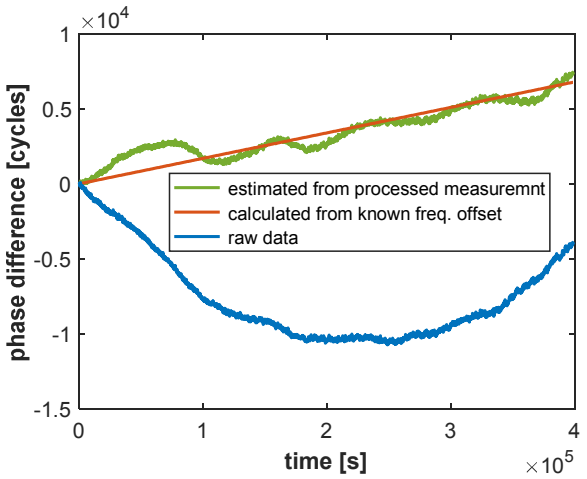

Fig. 2: Relative phase drift of the two clocks; calculated theoretically from the known frequency offset, obtained from the raw measurement data, and obtained with the proposed post-processing. Measurements performed over 1500 km-long link.

Thanks to the proposed post-processing algorithm, the relative phase drift between the two clocks may be estimated after a few days-long measurement session (see Fig. 2) and the frequency offset between clocks may be estimated with the uncertainty at the level of 10^{-17}, i.e. approximately an order of magnitude better than when the raw data are used.

[1] K. Turza, P. Krehlik, Ł. Śliwczyński, „Stability Limitations of Optical Frequency Transfer in Telecommunication DWDM Networks," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 67, 2020.