Clean-up laser system for the remote terminal of an optical clock

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The ultra-stable optical frequency signals produced by optical clocks may be transmitted to remote destinations by using actively phase-stabilized fiber-optic links. Thanks to applied phase noise cancellation schemes, the long-term instability of fiber links may be reduced to below 10^{-20} for 1000 s observation time[1]. In short terms, however, the noise cancellation is not fully efficient, because of inherently limited bandwidth of the noise cancelation loop. This leads to some residual phase noise of the remote optical signal, usually located in the spectral range from some Hertz to some hundreds of Hertz – see Fig. 1. This residual noise is not an issue when the fiber link is used for comparison of two remote optical clocks, but leads to signal quality degradation in real-time applications, as for instance optical comb synchronization or high-resolution spectroscopy.

In this work we present the clean-up system based on the ECL semiconductor laser which is stabilized with an ultra-stable optical cavity (12.5 cm, finesse of 300000), and in longer terms (i.e. for Fourier frequencies below 0.1 Hz) is phase-locked to the signal incoming from the fiber link. In the experiment being reported in this work we mimicked the target working circumstances by locking our clean-up system to the ultrastable laser (ORS by Menlo) with the electro-optic phase modulator used to generate the phase noise reproducing the residual noise of the fiber link – see Fig. 2. The performed measurements show efficient noise reduction for Fourier components above 1 Hz. In the next step we are going to perform the final evaluation with the real strontium optical clock operated in the FAMO laboratory in Toruń, and the fiber link operated by Poznan Supercomputing and Networking Center (PSNC).

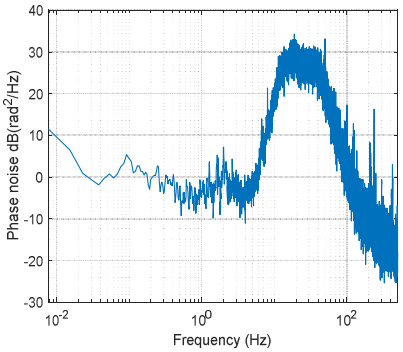

Fig. 1: Residual phase noise at the end of the fiber link.

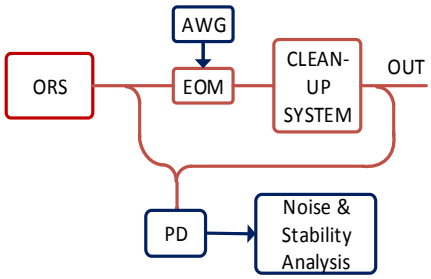

Fig. 2: Simplified experimental setup. ORS stands for optical reference system, PD - photodiode, EOM - electro-optic modulator, AWG - arbitrary waveform generator.

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[1] K. Predehl et al., "A 920-Kilometer Optical Fiber Link for Frequency Metrology at the 19th Decimal Place", Science, vol. 336, p. 441–444, 2012.