Indirect stabilization of optical frequency transfer over fiber by polarization and wavelength-division multiplexing

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A 184-meter polarization-maintaining optical fiber link is stabilized using Doppler cancellation. A λ_1=1560.0 nm primary signal is transmitted and serves to detect and compensate fiber noise. At the same time, a secondary signal (λ_2=1556.2 nm) is multiplexed with the primary one and transferred over the same fiber link. The secondary signal is shown to benefit from indirect stabilization thanks to the active noise compensation performed on the primary signal.

The Doppler cancellation technique is implemented on a fully fibered Michelson interferometer and using a Low Noise StemLab card by RedPitaya in combination with an acousto-optic modulator (AOM). Bringing together the local and remote link ends allows to get two Mach-Zehnder interferometers with short reference arms that are used for the out-of-loop characterization of both the primary and the secondary signal. Two different multiplexing methods are tested, namely polarization and wavelength-division multiplexing. The signals are multiplexed before passing the AOM and de-multiplexed again at the remote link end.

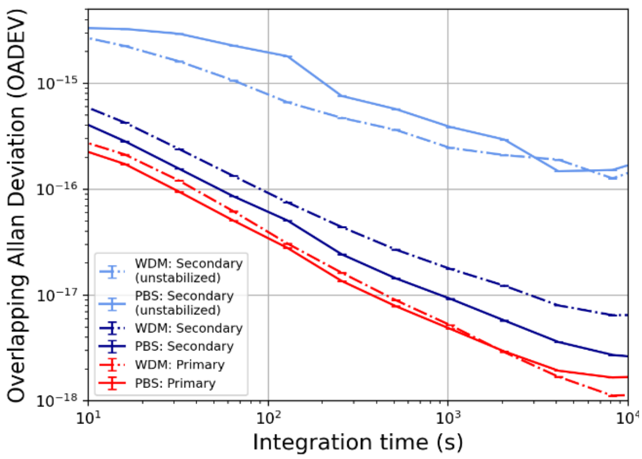

Fig. 1: Overlapping Allan Deviation depicting the frequency transfer stability of the primary and secondary signals. WDM: Wavelength-Division Multiplexer, PBS: Polarization Beam Splitter

The two methods perform similarly well in terms of transfer stability for integration times of 1 s or below. For longer integration times, the obtained Overlapping Allan Deviations (OADEV) in Fig. 1 reveal a clear effect of indirect stabilization of the secondary signal compared to when the primary one is not stabilized. While this is observed for both multiplexing methods, polarization multiplexing shows slightly better performance than wavelength-division multiplexing. In particular, at 1000 seconds averaging time we measure a 11.5 dB improvement for wavelength-division and a 16 dB improvement for polarization multiplexing, the difference likely being caused by the configuration of the multiplexing elements and the commonality of residual noise contributions between the two lasers. In both cases, the stability of the indirectly stabilized optical frequency transfer is found to be limited by the 5% relative fiber length that is not shared between the primary and secondary signal.

Such a fiber link simplifies the simultaneous transfer of multiple optical frequencies within and across research laboratory buildings. In particular, since the secondary frequency is not required for stabilization, its transmission can be freely interrupted and resumed at any time.