Optical link stabilization technique using digital electronics

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Summary

We have developed a compact Doppler-cancellation setup based on a digital phase locked loop implemented by a compact digital commercial board. This setup will be used to provide a stabilized fiber output to a compact transportable Fabry-Perot cavity[1]. We have found that the stand–alone digital control board performance is limited to a phase noise of -60 dBc/Hz at 1 Hz. Using an external reference, we were able to achieve a phase noise of -70 dBc/Hz at 1 Hz that complies with state-of-art Fabry-Perot cavities.

Motivation

Fabry-Perot cavities are widely used as frequency references to stabilize laser sources. Cavity stabilized lasers are of prime importance for optical frequency standards. Many laboratories are developing techniques that reduce the thermal noise of these cavities[2,3]. But this comes at the expense of very complex systems and active control of many technical parameters. On the other hand, practical applications require the realization of compact and transportable optical references. Such devices will also benefit from stabilized fiber outputs, for the distribution of the signal on the laboratory scale. Combining a fibered Michelson interferometer and digital control electronics is a simple way to make such a compact setup.

Results

Our setup is based on the well-known Doppler-cancellation scheme[4]. We show the obtained phase noise spectrum in figure 1 below with two configurations. The first set of results was obtained using the internal quartz oscillator of the digital control board and the second set of results was obtained by replacing the internal quartz oscillator of the board with a highly stable external clock signal from an ultra-stable Hydrogen MASER. We have taken the measurements for two cases i.e. free running state and phase locked state. This phase lock was achieved using the internal onboard Proportional Integral control. We see that there is a difference of 10 dB between each configuration and we conclude that the performance of the digital board clocked to the external clock precedes over the board clocked to the internal quartz for optical frequency transfer. All the tests were performed on a table top experiment.

In figure 2, we show the whole link setup enclosed in a 19 inches rack box which is compact and easily transportable. The box is supplied with a maximum power consumption of 70 Watts. The optical and the rf components are separately mounted on different breadboards while the Michelson reference arm is mounted on a separate temperature controlled breadboard. We have also added the setup for characterization of the stability of the link in the box so that we can check the frequency stability and the phase noise spectrum of the link at any time.

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1 A. Didier *et al.*, "Ultracompact reference ultralow expansion glass cavity", Appl. Opt., 57, nr 22, p. 6470-6473, 2018.

2 S. Häfner *et al.*, "8×10^{-17} fractional laser frequency instability with a long room-temperature cavity", Opt. Lett., vol. 40, nr. 9, p.2112–2115, 2015.

3 W. Zhang et al., Ultrastable Silicon Cavity in a Continuously Operating Closed-Cycle Cryostat at 4 K", Phys. Rev. Lett., vol. 119, nr. 24, p. 243601, 2017.

4 N. R. Newbury *et al.*, "Coherent transfer of an optical carrier over 251 km", Opt. Lett., vol. 32, nr. 21, pp.3056–3058, 2007.

Figures

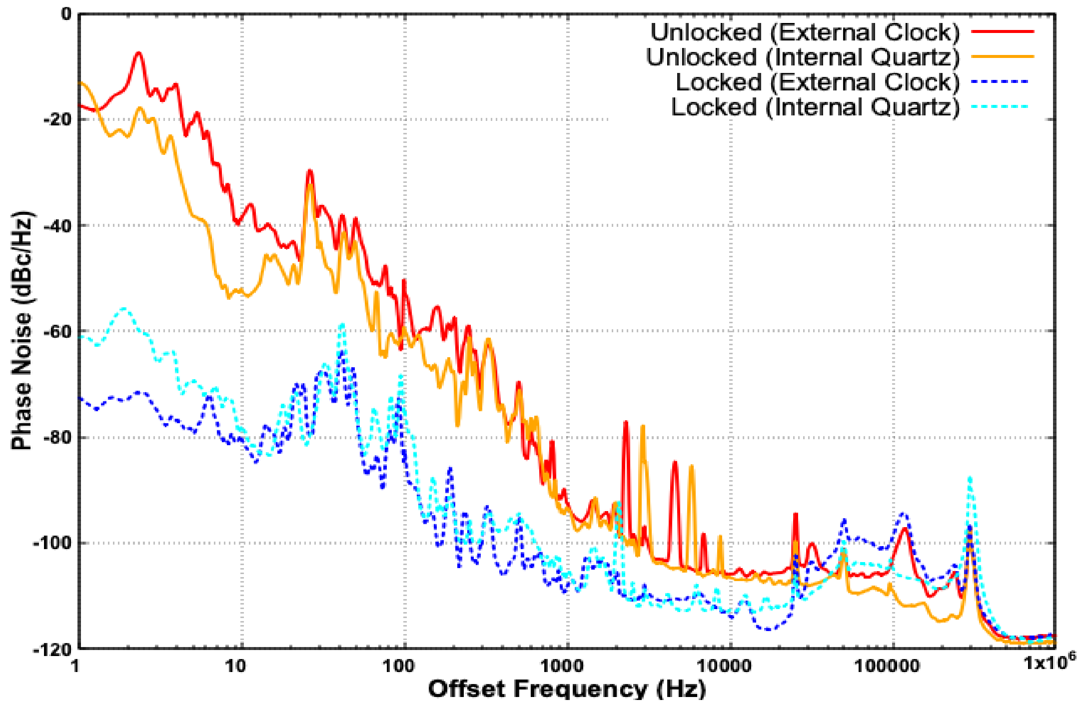

Fig. 1: Phase Noise spectrum of free running link clocked to internal quartz oscillator (orange straight line), free running link clocked to external clock (red straight line), locked link clocked to internal quartz oscillator (dashed light blue line), locked link clocked to external clock (dashed deep blue line).

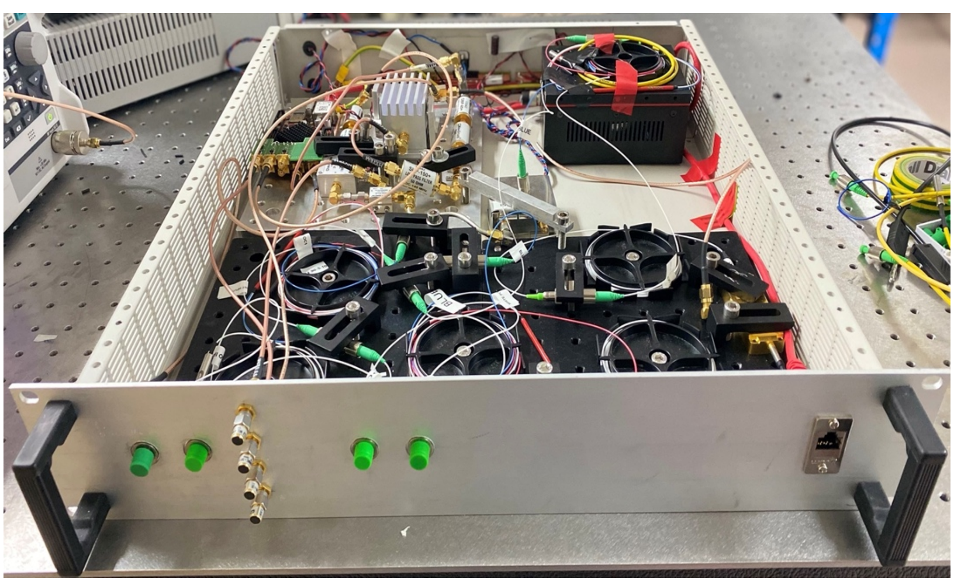

Fig. 2: Compact, transportable optical fiber link enclosed in a 19 inches rack box.