Out-of-loop frequency noise reduction of a Pound-Drever-Hall lock to an optical fiber delay line

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Laser frequency noise reduction is usually achieved by locking the laser to an ultra-stable Fabry-Perot cavity using the Pound-Drever-Hall technique. As Fabry-Perot cavities require fine alignment, spatial mode matching and are quite expensive, bulky, and fragile, other alternatives should be investigated, for example for space applications. Among them is the fiber-based delay-line interferometer, which can have strong frequency discriminator factor in a very compact and light design. This technique has already demonstrated experimentally very promising results[1]. In this paper, we don't investigate the fiber noise itself, but we focus on characterizing and reducing the out-of-loop frequency noise of the lock, which can limit the ultimate performance.

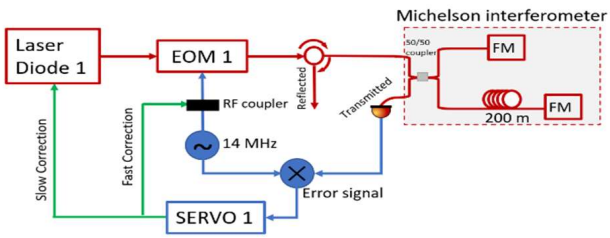

Fig.1: Laser locking set up

To measure the out-of-loop noise without being limited by the fiber noise, two laser diodes (model RIO ORION, 1542 nm) exhibiting a central frequency difference of 450 MHz are locked on the same interferometer and their beat noise is analyzed. Contrary to other fiber-based works that use heterodyne detection, we use the Pound-Drever-Hall technique. The setup of the lock of one laser is shown on Fig.1. The path imbalance is around 417 m corresponding to a free-spectral range of 497 600 Hz. The error signal is processed by a specially designed analog servo controller. Previous results[2] had demonstrated an out-of-loop white noise floor at 2×10^{-1} Hz/$\sqrt{\text{Hz}}$ up to 1 kHz which were attributed to discriminator nonlinearity. By increasing the servo controller bandwidth and thus reducing the RMS error level, we reduced this floor level below $10^{-1} Hz/\sqrt{Hz}$ and extended it up to 8 kHz (Fig.2). Out of loop noise floor optimization should be considered to reach fiber thermal noise floor operation, especially with diode laser exhibiting a larger white frequency noise component.

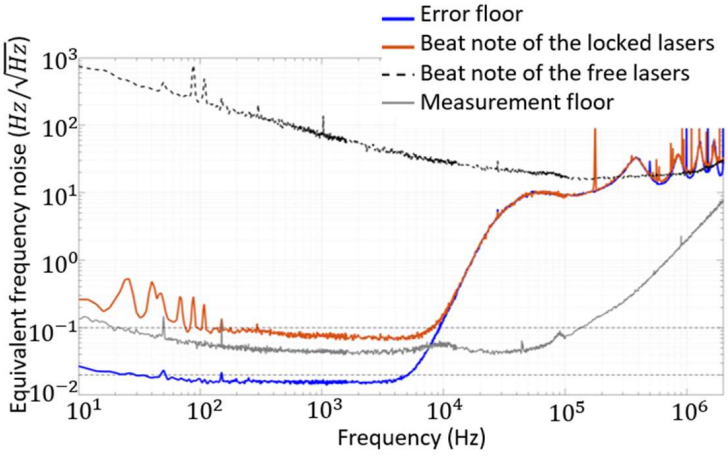

Fig.2: Out-of-loop locking frequency noise

[1] J. Dong, Y. Hu, J. Huang, M. Ye, Q. Qu, T. Li, and L. Liu, "Subhertz linewidth laser by locking to a fiber delay line," Appl. Opt., vol 54, p. 1152-1156, 2015.

[2] F. Audo, J. -P. Coulon and F. Kéfélian, "Experimental evidence of a fundamental noise floor at the tens of millihertz level in laser locking onto unbalanced fibre-based Michelson interferometer," CLEO/Europe-EQEC, Munich, Germany, 2017.

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