Noise of spectral transfer of laser frequency by locking to the direct difference of fiber interferometer signals

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Femtosecond laser frequency comb can achieve transfer of frequency stability between two lasers of different wavelength with a residual instability compatible with the most advanced optical clocks. Due to cost issue or reduced performance requirement, alternative techniques have been also developed such as the transfer cavity, either with bulk Fabry-Perot cavity or even fiber-based resonator[1]. Here we consider another technique introduced in ref [2] using a difference of interferometric signals provided by a fiber-based Mach-Zehnder interferometer. The setup is presented on Fig.1. The two lasers propagate in the opposite direction in the interferometer. The delay line is realized with a 500 m SMF-28 fiber on one arm and an acousto-optic modulator (AOM) is inserted in the other arm. The error signal to lock laser 2 on laser 1 is obtained by mixing the two heterodyne signals. An analog servo system is used to apply the correction to the slave laser.

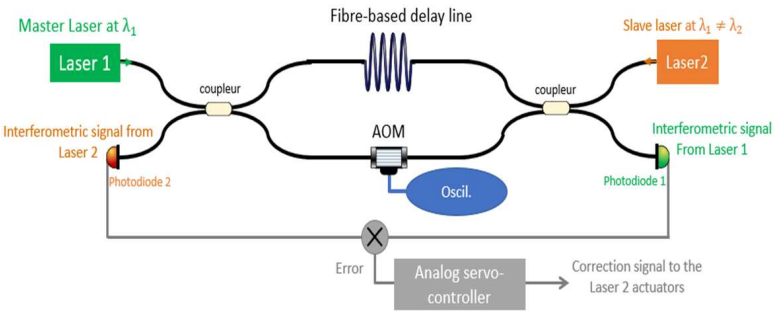

Fig.1: Experimental scheme of the spectral transfer

To investigate the noise limit of the technique, contrary to ref. [2] we used a direct subtraction of the interferometric signal with the mixer and a fully analogic servo system, as well as a smaller wavelength difference. Two RIO diode lasers were used, one at 1560 nm as reference and another at 1542 nm as the slave. A second interferometer is setup with the same reference laser and a second 1542 nm diode laser as slave. We measured the frequency of the beat note between the two slave lasers. As shown on Fig. 2, we demonstrated a transfer frequency noise below 1 $\mathrm{Hz}/\sqrt{\mathrm{Hz}}$ over the [100 Hz – 17 kHz] range with a promising minimum level of 0.2 $\mathrm{Hz}/\sqrt{\mathrm{Hz}}$, 14 dB below ref. [2]. We have investigated the different possible contributions to the residual noise including laser noise crosstalk and fiber noise coupling due to wavelength difference or polarization asymmetry.

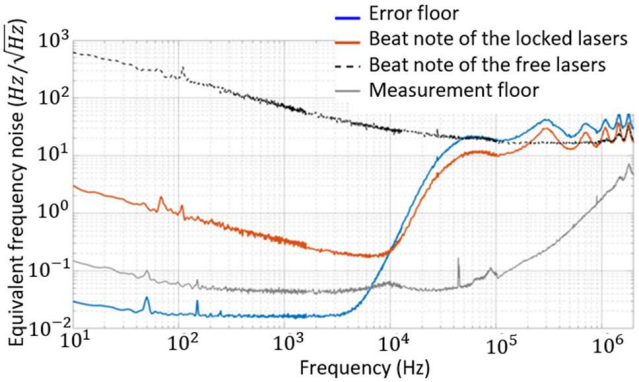

Fig.2: frequency noise characterization

[1] T. Steshchenko, K. Manamanni, H. Mouhamad, V. Roncin, and F. Du-Burck, "Limitations of frequency stability transfer in the near infrared using a fiber-based ring cavity", Opt. Lett, vol. 47, p. 5465-5468, 2022.

[2] N. Bourbeau Hébert, A.P. Hilton, P.S. Light, A.N. Luiten, "Hertz-level frequency comparisons between diverse color lasers without a frequency comb", Opt. Lett., vol. 45(15), p. 4196-4199, 2020