Simple hybrid digital and analog laser synchronization system

Mingwen Zhu[1], Shangsu Ding[1], Jianming Shang[1], Song Yu[1], Bin Luo[1]

[1]State Key Laboratory of Information Photonics and Optical Communications, Beijing University of Posts and Telecommunications, Beijing, China

Email: luobin@bupt.edu.cn

Typical fiber optic T&F transfer link uses two counter-propagating optical signals sending over the same fiber. However, the fiber's chromatic dispersion causes a propagation delay asymmetry when the frequencies of the two counter-propagating lasers differ. This asymmetry can be determined and accounted for through the link calibration, but the accuracy of time transfer depends critically on the accuracy and stability of laser's frequency offset[1]. This problem can be solved by laser synchronization. Traditional digital-only or analog-only locking in laser synchronization has a trade-off of accuracy and bandwidth. Current hybrid 'digital + analog' laser synchronization systems can slove the problem and achieve high accuracy, but they are complicated in error extraction. We present a 'digital + analog' laser synchronization system with a simple structure for synchronizing a distributed feedback (DFB) laser to an optical mode of a mode-locked laser (MLL) and achieved an RMS error of 0.23 Hz over 24 hours of operation. The analog locking part extracts the harmonics of the MLL on electric and feeds the error frequency directly to the acousto-optic modulator (AOM) by mixing and filtering. The digital locking part uses a bandpass filter (BPF) and an RMS detector to form a high-speed frequency meter, utilizing the transmittance properties of filter roll-off band to lock the laser frequency offset to the reference BPF. Due to the broad spectrum nature of the MLL, an MLL can also be used to synchronize multiple DFB lasers with large frequency offset. When not synchronized, the frequency offset's absolute variation exceeds 50 MHz in 2 hours, as depicted in Fig. 1(b). However, after running the digital locking part, the frequency offset varied less than 350 kHz over a 24-hour period, as shown in Fig. 1(c). Finally, after simultaneously operating the 'digital + analog' locking part, the two lasers achieve homodyne synchronization, and the frequency offset varies less than 2.5 Hz in 24 hours in Fig. 4(d), indicating reliable short and long-term stability.

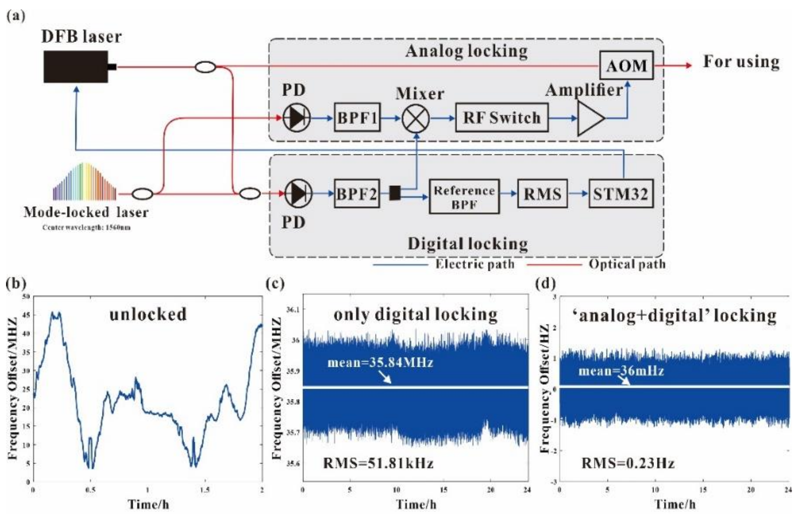

Fig. 1: (a) Hybrid 'digital + analog' laser frequency synchronization system. RMS: root mean square detector. (b) The laser frequency offset in a free-running state. (c) The laser frequency offset in 24 hours with only digital locking. (d) The laser frequency offset in 24 hours with 'digital + analog' locking.

[1] Ł. Śliwczyński, P. Krehlik, Ł. Buczek and H. Schnatz, "Synchronized Laser Modules With Frequency Offset up to 50 GHz for Ultra-Accurate Long-Distance Fiber Optic Time Transfer Links," in Journal of Lightwave Technology, vol. 40, no. 9, pp. 2739-2747, 1 May1, 2022,