Low-noise active mode-locked optoelectronic oscillator based on passive mode-locked laser injection

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Microwave frequency combs (MFCs) consisting of a series of discrete microwave signals with equal frequency spacing and stable coherent phase relationships[1], have been widely used in many fields recent years. With the development of the microwave photonics, we typically use an optical frequency combs (OFC) to generate the MFC. Mode locking is a well-known technique to generate broadband OFCs. Traditional passive mode-locked lasers[2], with their extremely low timing jitter[3], can theoretically be regarded as excellent sources to produce MFCs. However, the repetition frequency can only be tuned within a small range because this adjustment is achieved by changing the cavity length through moving parts. In this regard, active mode-locked oscillator schemes[4] based on Optoelectronic oscillators (OEOs) are proposed to achieve a larger comb interval tuning range. The MFCs generated by these oscillators have extremely low phase noise at high frequency offset, but poor phase noise characteristics at low-frequency offset, resulting in poor long-term stability of the microwave signals.

In order to reduce the phase noise of the MFC, especially in the low frequency part, in this abstract we proposed a scheme to inject a passive OFC into the active mode-locked optoelectronic oscillator (AML-OEO). The experimental setup of this scheme is shown in Fig. 1. A frequency stabled Ti: sapphire mode-locked laser is used as a high stability microwave source. The low-noise RF comb generated after photoelectric conversion will be divided into two parts. One part is extracted into a single frequency component by a tunable band-pass filter (BPF) to be used as the modulation signal for the AML-OEO, and the others is completely injected into the OEO loop through a Mach-Zehnder modulator (MZM). The reason why this scheme can reduce the phase noise of AML-OEO is that, a frequency synchronization of the passive optical comb and the active optical comb is achieved through injection. At this time, the low-frequency noise characteristics of the passive optical comb are transferred to the active optical comb. This conclusion has been confirmed in experiments in which passive optical combs were injected into a single-frequency OEO loop[5].

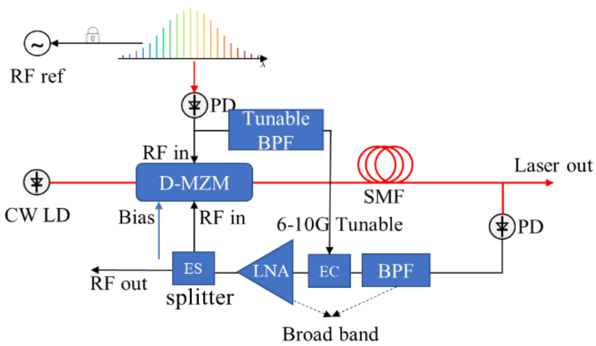

Fig. 1: Schematic diagram of low-noise active mode-locked optoelectronic oscillator.

[1] D.S. Citrin, “Connection between Optical Frequency Combs and Microwave Frequency Combs Produced by Active-Mode-Locked Lasers Subject to Timing Jitter”, Phys. Rev. Appl., vol. 16, art. no. 014004, 2021.

[2] H. A. Haus, “Mode-Locking of Lasers”, IEEE J. Sel. Top. Quant., vol. 6, p. 1173-1185, 2000.

[3] T. D. Shoki, “Ultra-low-noise monolithic mode-locked solid-state laser”, Optica, vol. 3, p. 995-998, 2016.

[4] B. Yang, “Active mode-locking optoelectronic oscillator”, Opt. Express, vol. 28, p. 33220-33227, 2020.

[5] H. Peng, “Photonic microwave synthesizer based on optically referenced sub-sampling phase-locked optoelectronic oscillator”, Opt. Commun. 499, art. no.127304, 2021.