RF-injection-locked Wideband-tunable(2-20 GHz) Low-phase-noise (－130 dBc/Hz) Optoelectronic Oscillator

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***Abstract*—An RF-injection-locked YIG-filter-based tunable (2-20 GHz) low-phase-noise (－130 dBc/Hz) optoelectronic oscillator with five orders of magnitude reduction in Allan variance is demonstrated.**

Keywords—Optoelectronic oscillator, Phase noise, Microwave injection, Allan variance, Frequency stability

I. Introduction

The optoelectronic oscillator (OEO) [1] can generate high-quality RF signals due to the ultra-high-Q cavity adopted in the system. The best OEOs are all based on long optical fiber with length up to 10 kilometers or more to serve as the high-Q energy storage medium. However, the cavity modes along with a long fiber are too densely spaced to be selected by an electronic filter, extra mode selection mechanism has to be introduced, typical of which include dual-loop [2] and RF injection [3] structures. Besides, a long fiber is also susceptible to the variation of ambient temperature, mechanical vibration and stress, which affect the stability of the OEO system. Phase-locked loop (PLL) structure [4] along with coarse and fine length tunning of the optical fiber needs to be used to realize a stabilized operation of the OEO. Dedicated control of multiple parameters is therefore required. When the function of frequency tunability is involved, the control will become more complicated.

In this paper, we demonstrate a frequency-tunable OEO using a simple RF-injection scheme to obtain a frequency-stabilized operation for wideband-tunable low-phase-noise microwave generation. The OEO is tunned using an Yttrium Iron Garnet (YIG) filter. A tunable RF signal is used as the injection seed for frequency stabilization. Frequency-stabilized tunable microwave covering 2-20 GHz with the phase noise below －130 dBc/Hz at 10 kHz offset from the carrier frequencies is realized. After the RF injection, the phase noise at a close-in frequency of 10 Hz offset from the carrier frequency is reduced by 45 dB to a level of －43.9 dBc/Hz, and the Allan variance corresponding to an observation time of 100 ms is reduced from 3.40 E－17 to 3.99 E－22.

II. Experiment and Result

A. Experiment setup and principle

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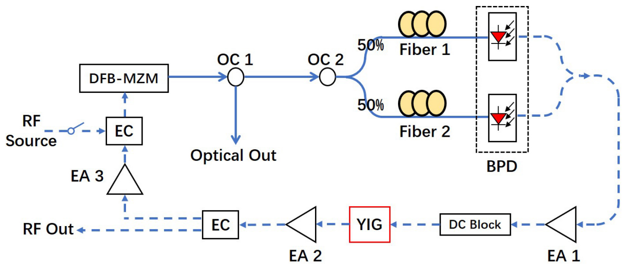
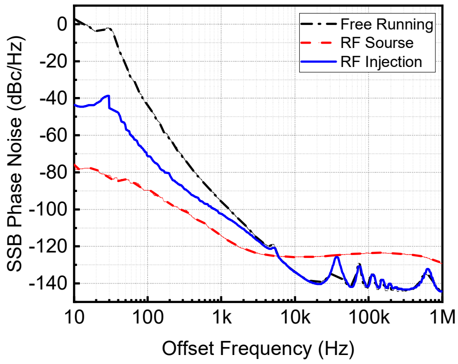


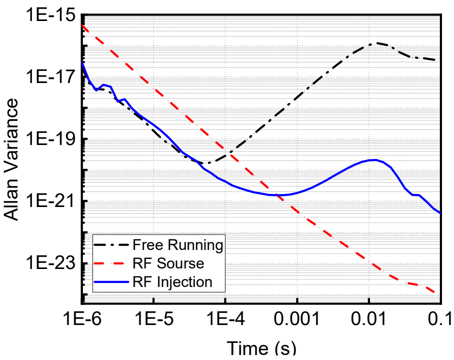
Fig. 1. Schematic of the OEO with RF injection. OC: optical coupler; BPD: balanced photodetector; EA: electrical amplifier; YIG: Yttrium Iron Garnet Filter; EC: electrical coupler.

The experimental setup is shown in Fig.1. The DFB-MZM is a DFB laser co-packaged with a Mach-Zehnder Modulator (MZM). The light is divided into two parts by a 5:5 optical coupler (OC) and converted into RF signal using a balanced photodetector (BPD) after passing through a 5 km and a 300 m fiber, respectively. After amplified by two electrical amplifiers (EA, total gain: 46 dB), passing the DC-Block and filtered by the YIG filter, the RF signal is divided into two paths by an electrical coupler (EC). One is as the output RF signal of the OEO, while the other is amplified by the third EA (gain: 23 dB) and then modulated on the DFB-MZM. RF signal from the microwave source (Rohde & Schwarz SMA100B) is injected into the RF port of the DFB-MZM using another EC. The optical output of the OEO is analyzed by an optical spectrum analyzer (Advantest Q8384), and the phase noise and Allan variance are analyzed by a phase noise analyzer (Rohde & Schwarz FSWP50, 1 MHz to 50 GHz).

B. Results



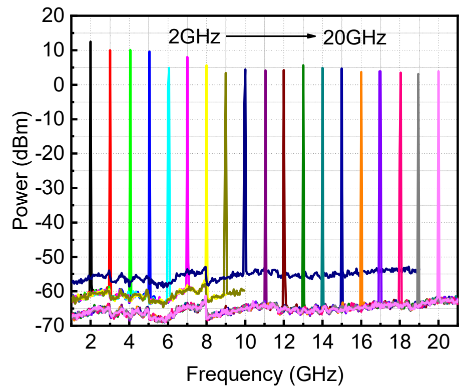
(a)



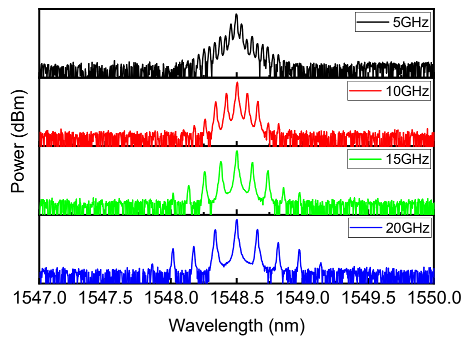
(b)

Fig. 2. (a) SSB phase noise with and without RF injection; (b) Allan variance with and without RF injection of OEO 10 GHz microwave signal

Fig. 2(a) shows the phase noise and Allan variance curves of the free-running OEO, the injection-locked OEO and RF source, respectively, when the YIG filter is tuned to 10 GHz. It can be seen that the phase noise at 10 Hz offset from the carrier frequency is reduced from by about 45 dB to −43.9 dBc/Hz. Meanwhile, the phase noise at 10 kHz offset from the carrier frequency shows no degradation. Fig. 2(b) shows that the Allen variance corresponding to the observation time of 100 ms is reduced from 3.40 E−17 to 3.99 E−22, which is optimized by five orders of magnitude. The injected RF signal has greatly improved the phase noise at the near-carrier frequency without affecting the phase noise far away from the carrier frequency, and improves the stability of the OEO signal.



(a)



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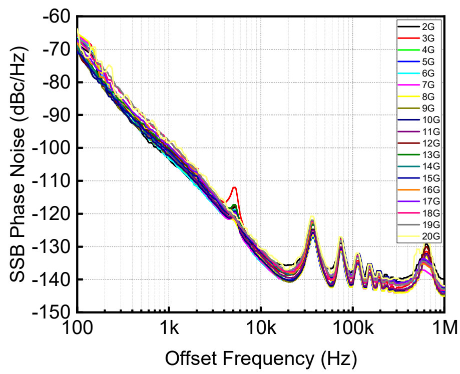

(c)

Fig. 3. (a) Overlapped RF spectrum with RF injection; (b) Overlapped optical spectrum corresponding to different frequencies; (c) Overlapped SSB phase noise with RF injection.

Fig. 3(a) shows the frequency tunability of the injection-locked OEO when the YIG filter is tuned from 2-20 GHz by adjusting its control current with a minimum tuning step of about 70 MHz/mA. Fig. 3(b) shows the optical spectrum corresponding to the optical output signal of the OEO system at different oscillation frequencies. It can be seen that the modulation sideband spacing of the optical output signal corresponds to the oscillation frequency of the OEO. Fig. 3(c) shows the phase noise corresponding to different frequencies in the tuning range with a tuning step of 1 GHz. The phase noises at 10 kHz offset from the carrier frequency are all below −130 dBc/Hz within the whole tuning range.

III. CONCLUSIONS

A frequency-stabilized wideband tunable OEO with low phase noise is demonstrated. This system can achieve tunable output from 2 GHz to 20 GHz, with the phase noise below −130 dBc/Hz at 10 kHz offset from the carrier frequencies. By using the RF-injection scheme, the phase noise at 10 Hz offset from the carrier frequency is reduced by 45 dB, and the Allan variance corresponding to an observation time of 100 ms is reduced from 3.40 E−17 to 3.99 E−22.

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