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Temperature stabilization techniques for High Stability LO Generation using a Hybrid Integrated Dual InP-Si_3N_4 Laser Source

(Student paper)

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We propose a study of temperature stabilization techniques for a hybrid integrated InP-Si_3N_4 laser under free running condition for microwave generation based on optical heterodyning. Long-term drift exhibited by the device over certain time is performed as key parameter. Free-running drift reduction is one of the goals of this experiment which has been measured along different scenarios. Optical drift has been improved from up to 500 MHz, in the worst case, to around 100 MHz measured over 6 hours on a thermal controlled environment.

Keywords: *microwave photonics, integrated optics*

INTRODUCTION

To the date, a wide range of applications field has RF frequency generation as its core function. As the requirements are becoming more demanding, especially in terms of increase the data capacity. There is an interest of improving this capacity and the flexibility [1]. All this driven by the need to work in higher frequency bands to enable large bandwidth availability. Although conventional RF based-on device are capable to reach high frequencies up to millimeter-Waves, high-end microwave electronic mixers and circuitry are bulky, heavy, expensive and sensitive to electromagnetic interference (EMI). Applications relying on the interfacing between radiofrequency (RF) signals and optical fiber network segments, call for flexible, agile and compact devices. Such as global wireless fifth generation (5G) communications [2]**,** radar based civil surveillance [3], fast analog-to-digital converters [4] and clock recovery systems [5]. Moreover, RF systems with increased complexity, large frequency tuning range and broad bandwidth are urgent for signal generation and processing areas.

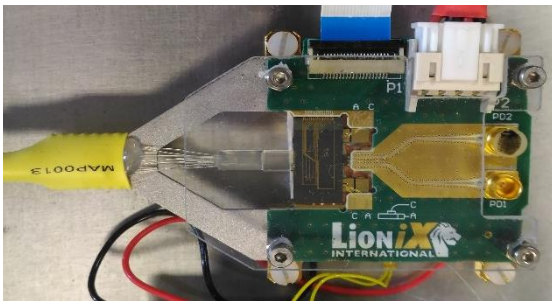
Microwave Photonics (MWP) emerges to be a promising and low-cost alternative. In this case, the local oscillator RF signals can be distributed using optical fiber instead of electrical connections, bringing important advantages in terms of mass, power and volume. These advantages fueled the development of MWP technology, mainly based on discrete components interconnected through optical fibre. This approach has been shown to limit energy-efficiency and scalability, and, as a result, high volume application. In addition, optical fibre interconnections, sensitive to thermal fluctuations, introduce optical path length variations that affect the quality of the generated signals [6]. Photonic integration has been identified as a technology that can significantly reduce this dependence, since all components in the system and their interconnections are fabricated in a single chip, a Photonic Integrated Circuit (PIC). The use of photonic integration technology for microwave photonic applications has recently coined the term of integrated MWP (iMWP).

Microwave photonic frequency generation can range from few MHz up to THz range facing the conventional RF LO generators. However, despite of integrating the two lasers on the same chip, the fact that these are two free-running lasers usually results in a large phase noise of the beat note and long-term drift of the frequency [7]. While the two lasers can have very low intrinsic linewidth (less than 1 kHz), the RF beat-note still exhibits a long-term drift due to electrical, thermal & noise instabilities. This issue is not acceptable specially if this drift reaches the range of the RF signal channelizing producing an overlap between different channels. Even if a stabilization technique is used to control the lasers, such as optical phase locked loop or injection locking, the amount of drift could be problematic. Specially, if lasers go out of range of the control system used. In this paper, we present a thermal study of a hybrid integrated dual laser using different approaches in order to reduce the amount of drift and improve the performance of the RF generated LO.

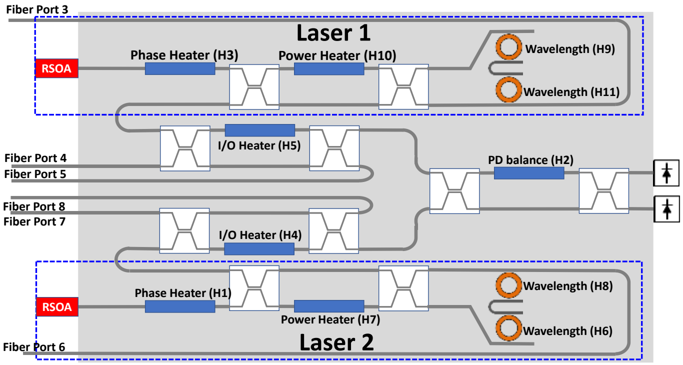
DEVICE DESCRIPTION

An InP/Si3N4 hybrid integrated dual laser module will be used in this work. The device is shown schematically in **Fig. 1 (b)**. As can be observed, it includes two identical laser structures, which are outlined on the figure using blue dashed boxes labeled Laser1 and Laser2 respectively. Each laser cavity is formed through hybrid integration of an

InP Quantum-Well (QW) gain chip (red boxes) and a Si3N4 (proprietary Si3N4 waveguide technology from LioniX International) chip (grey shaded area) using butt-coupling. The InP gain chip is double-pass reflective semiconductor optical amplifier (RSOA) through high-reflective (HR) coating on the leftmost edge, which forms one of the cavity mirrors. The other mirror is an integrated mirror structure in the Si3N4 substrate, based on a pair of micro ring resonators (MRR-A and MRR-B) which provide a wavelength tunable optical feedback. The two MRRs have Free Spectral Range (FSR) around 1.6 nm (200 GHz), with slightly different radiuses to enable wavelength tuning through the Vernier effect. In between the two mirrors, the lasers include a thermally adjustable Phase Tuning Section (PTS) that allows fine tuning of the cavity length for output power maximization and a 2x2 symmetric Mach-Zehnder Interferometer based Thermo-Optic Power Coupler (MZI-TOPC) [8] which allows control of the amount of light fed back to the laser cavity. A photograph of the InP/Si3N4 hybrid integrated dual laser module is shown in Fig. 1 (a).



(a)

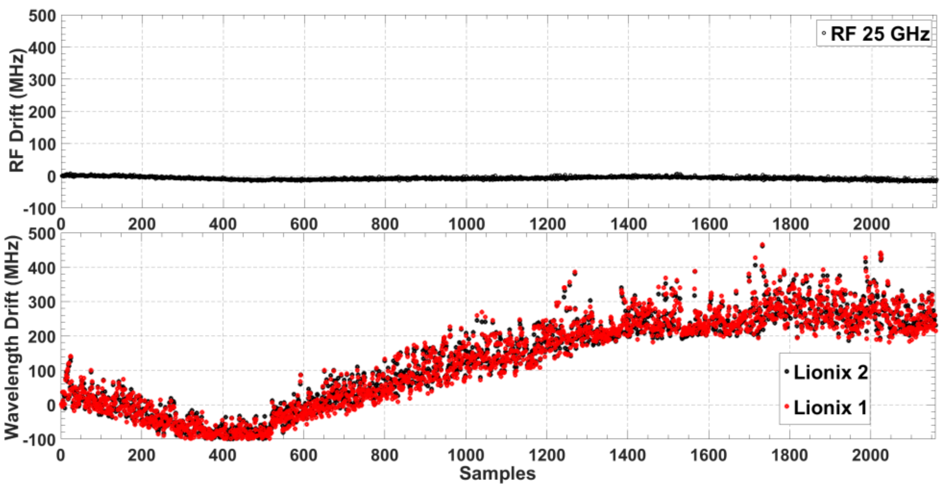


(b)

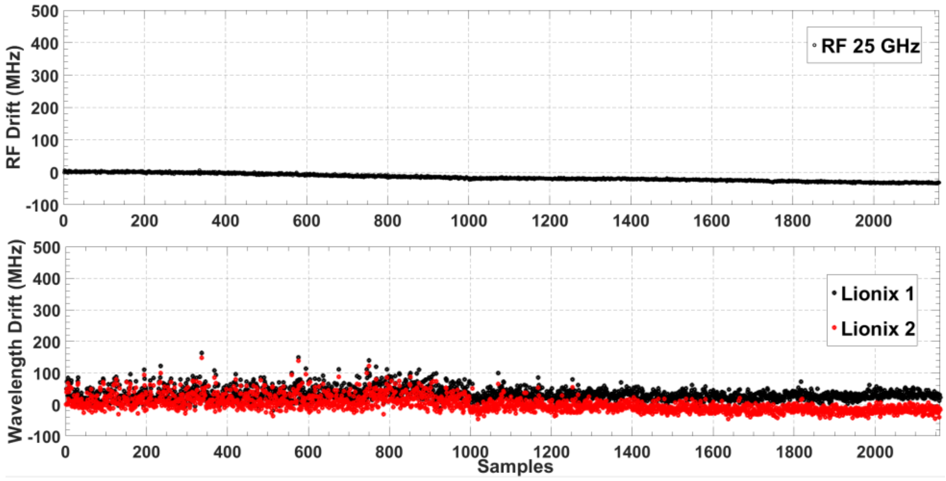
Fig. 1. (a) InP-Si3N4 hybrid integrated dual laser module is assembled on a thermally controlled base. (b) Schematic representation of the device.

RESULTS

The emission wavelength of the lasers during this experiment is around 1550 nm. The current injected into the gain section of each independent laser is 40mA, while the H5 and H4 heaters used to control the external coupling ratio on both lasers are biased at 13.632 V and 13.55 V, respectively. Tuning the biasing point of these heaters we can maximize the optical power at each laser output. The heaters that control the wavelength setting H9/H11 and H8/H6 are biased with a voltage of 0 volts and 11,159 volts, respectively for Laser 1 and Laser 2, so that an optical frequency difference between both lasers is established at 25 GHz. Fig. 2 shows the long-term drift of electrical beat-note RF signal (upper) and optical drift (lower) measured over 6 hours. Two different approaches have been measured. In Fig. 2(a) the measurement was taken with a standard optical breadboard while Fig. 2(b) was measured using a water-cooled breadboard where the temperature of the heat-sink mass was fully controlled by a Chiller. As it can be notice, the first approach the optical drift goes up to 500 MHz while with the second approach the drift keeps around 100 MHz exhibiting a one fifth improvement with respect the first approach.



(a)



(b)

Fig. 2. Temporal evolution of the drift of the InP/Si3N4 hybrid integrated dual laser module measured over a period of 12 hours. Optical drift of each laser of the dual module (below). Electrical drift of the generated RF frequency (above). (a) Using standard-optical breadboard. (b) Using water-cooled breadboard with chiller

Fig. 2 (a) and (b), upper, shows the electrical drift of the generated RF tone for each approach. We can see that the two approaches are quite similar. Despite the fact that both lasers are independent, they are close to each other (mm distance). They share same thermal control. The thermal fluctuations produce similar the optical drift on each laser. The electrical beat note is generated as product of the wavelength difference between Laser 1 and Laser 2, so if the displacement produced by thermal drift of each laser is synchronized, the drift on the RF beat-note reduced. As shown in Fig. 2 (a) and (b), they have similar behaviour that ranges from -42 MHz to +18 MHz with respect to the starting RF frequency.

CONCLUSSIONS

We have presented temperature stabilization study of an InP/Si3N4 hybrid integrated dual laser. Two different approaches have been compared in order to reduce drift of the lasers. We demonstrated a one-fifth reduction of the optical drift using a fully temperature-controlled environment keeping both lasers around 100 MHz drift, what is more suitable for a potential stabilization system. The wavelength drifts produced by thermal fluctuations when lasers are under the same control are correlated. This results on a reduction of the electrical drift of the generated RF frequency. We have measured an electrical drift that ranges between -18 MHz to 48 MHz with respect to the initial frequency measured over 6 hours under free running condition in both approaches.

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