Fully Integrated Photonic Microwave Tracking Generator on Heterogeneous III-V/Si Platform

Rui-Lin Chao[1-3], Linjun Liang[1,4], Jin-Wei Shi[1*,2], Jared Hulme[1], M. J. Kennedy[1], Tin Komljenovic[1], Doug Baney[5], Bogdan Szafraniec[5], and J. E. Bowers[1]

[1]*Electrical and Computer Engineering Department, University of California Santa Barbara, California, USA*
[*]*E-mail: jwshi@ece.ucsb.edu*
[2]*Department of Electrical Engineering, National Central University, Taoyuan, Taiwan*
[3]*Department of Photonics, National Chiao-Tung University, Hsinchu 300, Taiwan*
[4]*Institute of Lightwave Technology, Beijing Jiaotong University, Beijing, China*
[5]*Keysight Laboratories, Keysight Technologies, Santa Clara, California, USA*

Abstract: Fully-integrated photonic microwave tracking generators are demonstrated for the first time. By sweeping the wavelength separation among two-locked DFBs and one tunable laser, a two-tone photo-generated RF signal with tunable difference in frequency can be generated.

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I. Introduction

The generation, modulation, wireless transmission, and detection over hundreds of GHz bandwidth over the radio-frequency (RF) to millimeter-wave (MMW) spectrum is important for next-generation wide bandwidth measurement instruments (network analyzer) [1] and wireless communication at the millimeter-wave or THz wave bands [2]. However, there are many challenges to build such a wide-band system, such as the limited fractional bandwidth of the impedance matching circuit and the very high propagation loss in a metallic waveguide. The photonic approach is one possible solution to overcome the afore-mentioned problems [1,2]. By using the III-V monolithic [3] or heterogeneous silicon-III/V [4] technology, we can integrate all the essential optical-to-electrical (O-E)/electrical-to-optical (E-O) components on one single chip. Recently, this becomes a major trend to further reduce the size, cost, and energy consumption of these photonic systems. In this work we demonstrate a novel fully integrated photonic micro/millimeter wave tracking generator on the heterogeneous III-V/silicon platform. By sweeping the wavelength separations among three on-chip lasers and using heterodyne-beating in on-chip fast PDs, we can successfully generate two-tone signals with wide tunability in the difference between two frequencies. Such a chip has potential applications for instruments for wideband (THz) vector network analyzer [1,5], optical dispersion analysis of single-mode fiber [6], and frequency-hopping spread spectrum (FHSS) wireless communication systems [7].

II. PIC Structure

Figure 1 (a) shows the conceptual optical and electrical spectra, which are used to illustrate the working principle of our tracking generator. As shown in the optical spectra, we can lock the lasing wavelengths of two distributed feedback lasers (DFB) by use of an external (off-chip) optical phase locked loop (OPLL)[1]. By varying the offset frequency (Δf) in this loop, we can tune the separation of wavelengths between these two DFBs within the range of around 0.3 to 10 GHz. The locked two optical wavelengths are further combined with the output from a tunable laser (ring bus ring; RBR) [4] and then fed onto a high-speed photodiode (PD) for two-tone microwave/millimeter-wave (MMW) signal generation through the heterodyne-beating process. As shown in the microwave spectrum, the generation of a two-tone signal with the central frequencies at f_{o1} and f_{o2} and a tunable difference in frequency ($\Delta f = f_{o1} - f_{o2}$) can be expected. Here, the maximum value of central frequency is limited by the bandwidth of our on-chip PD, which is around 70 GHz [4]. Figure 1(b) and 2 shows the function block diagram and a picture of the demonstrated photonic integrated circuit (PIC) chip. The chip is composed of three parts. The first is the light source, which is composed of two DFB lasers and one RBR tunable laser. The second is the optical phase modulator and the third is a high-speed photodiode for heterodyne-beating signal generation [4]. The purpose of the integrated optical phase modulator is for generating multi-tone RF signal and more advanced fiber dispersion analysis measurement [6]. Based on our layout of the optical path, one of the photo-generated two-tone signals (f_{01} or f_{02}) can be separately extracted from PD 1 or 2, respectively.

III. Measurement Results

Figure 3 (a) shows the measured heterodyne-beating RF spectra generated from an off-chip high-speed photoreceiver module in our OPLL under different setting of offset frequency (Δf), which represents the separations of wavelengths of two-locked on-chip DFB lasers. As can be seen, by controlling the setting values of Δf (1~6 GHz), we can sweep the wavelength separations of these two locked DFB lasers. Figure 3 (b) shows the measured heterodyne beating RF spectra of two-locked and free running DFB lasers. We can clearly see that after locking, there is a narrowing in the measured instaneous RF linewidth. During our tracking generator experiment, we choose the central frequency at around 35 GHz and measure one of the two-tone signal output from PD 1. Figure 4 (a) shows the measured RF spectra of PD 1 under the sweeping of Δf from 3.6 to 7.6 GHz

[1]D2-135 offset phase lock servo; Vescent Photonics, Inc. 14998 W 6th Avenue, Suite 700, Golden, CO, 80401

in our OPLL (two-locked DFB) as discussed in Figure 2. Apparently, the beating frequency f_{o1} can be remotely controlled by the offset frequency Δf in our two-DFB locked OPLL. Figure 4 (b) shows the comparison of measured output RF spectra from PD 1 with/without tracking operation. For the case of non-tracking operation, we just measure the heterodyne beat signal from tunable laser and free-running DFB laser. As can be seen, the measured instaneous RF linewidths are pretty similar for both cases.

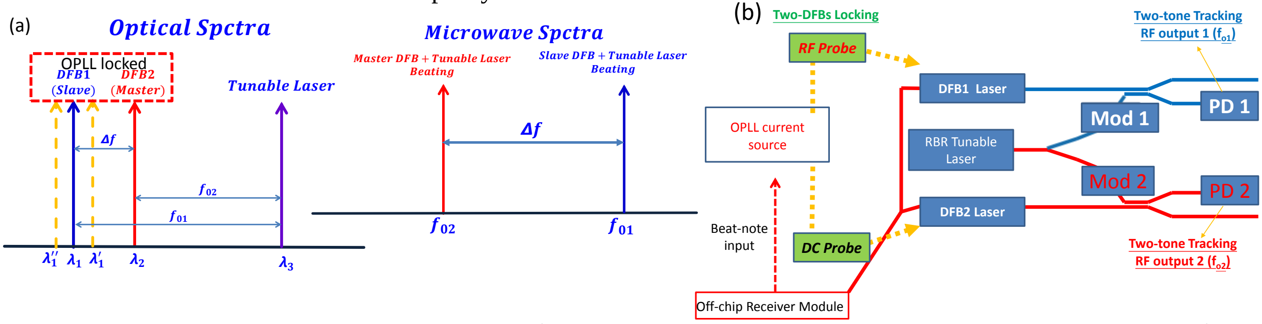

Fig. 1. (a) Conceptual optical and electrical spectra of proposed tracking generator during operation. (b) Function block diagram of our proposed photonic integrated circuit (PIC)

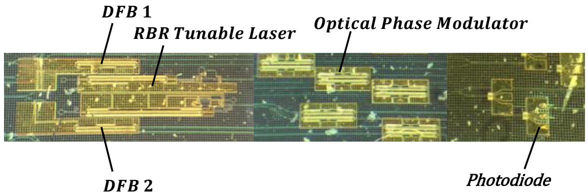

Fig. 2. Top-view of fabricated photonic micro/millimeter wave tracking generator on the hybrid silicon-III/V platform

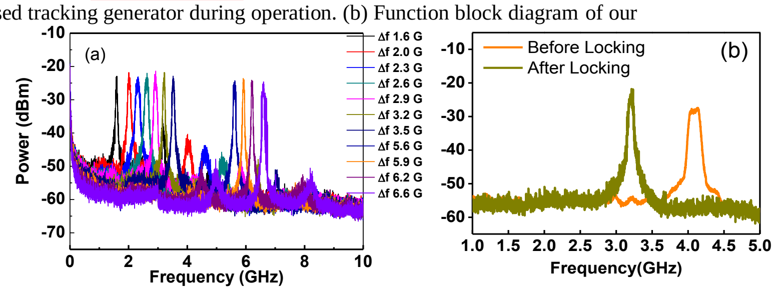

Fig. 3. (a) The measured RF spectra of beat-note in OPLL of two-locked on-chip DFBs. (b) The measured RF spectra before and after OPLL locking.

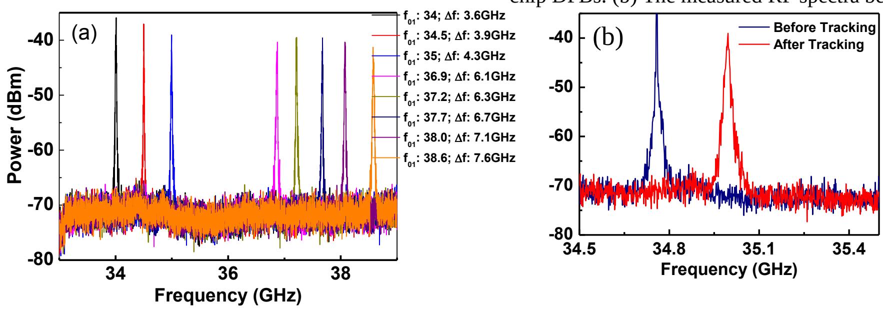

Fig. 4. (a) The measured RF spectra of tracking generator from PD1 under sweeping of Δf (b) The measured RF spectra before and after tracking operation.

IV. Conclusion

A novel fully integrated photonic microwave/MMW tracking generator is demonstrated for the first time. A two-tone RF signal with a wide tunability in their difference of frequency. Such novel chip has strong potential in the applications of next generation vector network analyzer, optical system for fiber dispersion analysis, and FHSS communication.

V. References

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