2007 Asia-Pacific Microwave Photonics Conference

AP-MWP 2007

Technical Digest

- **Sponsors**

Korean Institute of Communication Sciences (KICS)
Korea Institute of Information & Telecommunication Facilities Engineering (KIITFE)
The Institute of Electronics Engineers of Korea (IEEK)
Optical Society of Korea (OSK)

- **Technical Co-sponsors**

IEICE Electronics Society
IEEE Lasers and Electro-Optics Society (IEEE LEOS) Korea Chapter
IEEE Microwave Theory and Techniques Society (IEEE MTT-S) Korea Chapter

- **Supported by**

Korea Tourism Organization
Samsung Electronics Co.

April 25-27, 2007
The Suites Hotel, Jeju Island, Korea
http://www.ap-mwp2007.org

Harmonic Frequency Up-Converters Based on Actively Mode-Locked Multi-Section DFB Lasers for 60GHz Radio-on-Fiber Systems

Kwang-Hyun Lee (1), Woo-Young Choi (1), Young-Ahn Leem (2), Kwang-Seong Choi (2), Hyunsung Ko (2), and Kyung-Hyun Park (2)

1. Department of Electrical and Electronic Engineering, Yonsei University, 134, Shinchon-Dong, Sudaemoon-Ku, Seoul, 120-749, Korea
E-mail: wchoi@yonsei.ac.kr

2. IT Convergence&Components Lab. Electronics and Telecommunications Research Institute
E-mail: khp@etri.re.kr

***Abstract* — We demonstrate harmonic millimeter-wave frequency up-converters based on actively mode-locked multi-section DFB lasers that produce optical multi-modes separated by f_{LO}. In our scheme, f_{IF} along with mode-locking f_{LO} is applied to the gain section of the device and up-converted to the desired millimeter-wave band. By using this method, we successfully up-convert 10Mbps QPSK data at 500MHz f_{IF} into 60GHz band, corresponding to the 6th harmonic component of f_{LO}.**

***Index Terms* — Harmonic up-converters, actively mode-locked lasers, radio-on-fiber systems.**

I. INTRODUCTION

Optical frequency up-converters, which translate the data carried by the intermediate frequency (f_{IF}) to the desired radio frequency (f_{RF}) using optical devices, are key components in radio-on-fiber (RoF) systems [1]. In particular, optical harmonic millimeter-wave frequency up-converters translating IF signal to the millimeter-wave band corresponding to the integer multiple of the local oscillator frequency (f_{LO}) are very attractive because it can replace the expensive electrical mixers in the millimeter-wave RoF systems.

Generally, the optical harmonic up-converter consists of a square low device such as a photo diode (PD) and an optical device generating optical multi modes and the up-converted signal can be obtained by mode-beating between optical multi modes.

Mode-locked lasers have been considered as a promising candidate for the generation of optical multi modes because they can generate phase correlated optical modes which guarantee the good phase quality of the beating signal. Especially, monolithic semiconductor mode-locked lasers are of great interest due to their compactness and stability [2-3].

In this paper, we demonstrate that an actively mode-locked multi-section DFB (AML-MS DFB) laser can perform harmonic up-conversion. In this proposed method, the AML MS-DFB laser produces optical multi modes separated by f_{LO} and f_{IF} at the same time by injecting electrical f_{LO} and f_{IF} signals to the gain section. The desired up-converted signal is obtained by mode beating in PD. As a demonstration of this method, 10Mbps QPSK data at 500MHz are successfully up-converted to 60GHz band corresponding 6th harmonics of AML MS-DFB laser fundamental frequency, and the quality of the resulting up-converted signal is characterized.

II. EXPERIMENTAL SETUP AND RESULTS

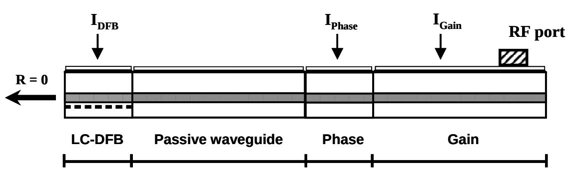

Fig. 1. MS-DFB Laser.

A. AML MS-DFB Laser

Fig.1 shows the MS-DFB laser used as a harmonic up-converter in our investigation. As shown in the figure, it is composed of DFB, passive waveguide, phase control, and gain sections. Phase control and gain sections adjust the phase and amplitude of the feedback optical signal, and the length of the passive waveguide section is set for the desired mode-locked frequency. With the proper bias condition applied to each section, the laser can be passively mode-locked

(PML) and the optical short pulse is emitted. Details of passive mode locking characteristics of the device without a saturable absorber can be found in [4]. The measured RF spectrum of PML-MS DFB laser is shown in Fig. 2(a). The pulsation frequency (fundamental frequency: f_{LO}) is about 10.814GHz at the bias condition of I_{DFB}=54.38mA, I_{Phase}=10mA, and I_{Gain}=150mA. However, the broad linewidth of the generated signal is not suitable for such application as phase modulated data transmission commonly used in wireless communications. This problem can be solved by the injection of electrical signal having the same pulsation frequency into the gain section through the RF port.

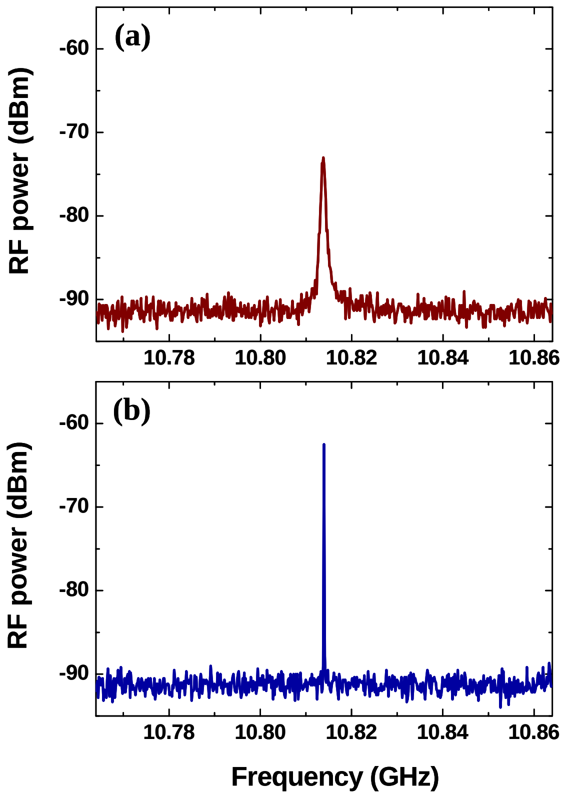

Fig. 2. Measured RF spectrum of (a) passively and (b) actively mode-locked MS DFB laser.

By the injection of the electrical signal, the device is actively mode-locked (AML), and the quality of the generated signal follows the quality of the injected electrical signal. Fig. 2(b) shows the measured RF spectrum of AML-MS DFB laser. To analyze the generated signal quality, we measured phase noises of the fundamental frequency of the PML and AML MS DFB laser, and the results are shown in Fig. 3. The measured phase noise value at 100kHz offset for the generated signal by PML and AML MS DFB laser is -59.17dBc/Hz and -78.83dBc/Hz, respectively. From this result, it can be confirmed that the phase quality of the generated signal is drastically improved by the electrical signal injection.

Fig. 4 shows the measured optical spectrum of the emitted optical output signal from AML-MS DFB laser. With many optical modes as shown in the optical spectrum, the device can produce many harmonic frequency components in RF domain by mode beating. In this investigation, the 6th harmonic frequency (64.88GHz) was used for the demonstration of harmonic up-conversion.

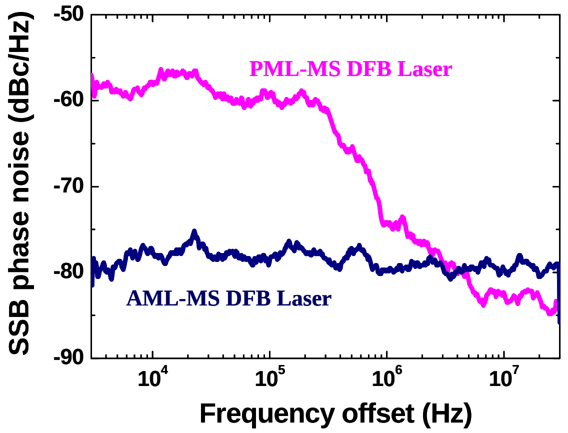

Fig. 3. Measured phase noises.

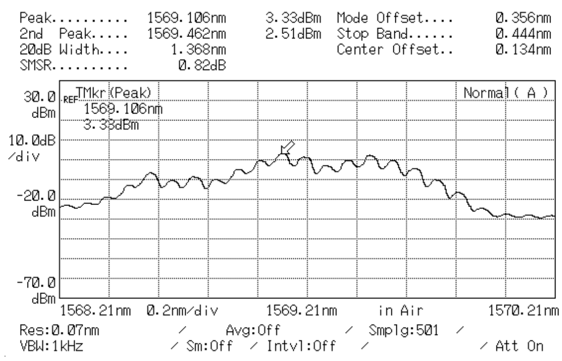

Fig. 4. Measured optical spectrum of AML-MS DFB laser.

B. HARMONIC UP-CONVERSION

In order to carry out the harmonic up-conversion using the AML-MS DFB laser, 10Mbps QPSK data at f_{IF} of 500MHz as well as f_{LO} of 10.814GHz for active mode-locking was applied to the gain section through the attached RF port as shown in Fig. 5. Therefore, optical sidebands separated by f_{IF} from optical multi modes generated by AML-MS DFB laser shown in Fig. 4 are produced and the electrical sidebands are generated f_{IF} away from f_{LO} by mode beating in PD. Effectively, the AML-MS DFB laser performs frequency up-conversion of f_{IF} into $f_{LO} \pm f_{IF}$. Furthermore, many harmonic optical modes of AML-MS DFB laser can be utilized for harmonic up-conversion, where f_{IF} is up-converted into $nf_{LO} \pm f_{IF}$. The RF spectrum of the 6th harmonic up-converted data signals are shown in Fig. 6. The spectrum clearly shows the up-converted double sideband data signals at 500MHz (f_{IF}) away from 64.88GHz ($6 \times f_{LO}$). The inset magnifies the lower sideband up-converted data. The applied f_{IF} and f_{LO} power were 19dBm and -6dBm, respectively. The up-converted data were down-converted by a 60GHz band self-heterodyne detector [5], and the down-converted data were analyzed by the vector signal analyzer (VSA).

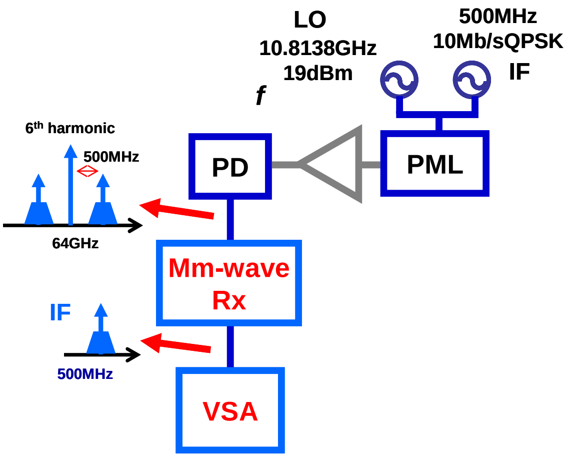

Fig. 5. Experimental setup for harmonic up-conversion.

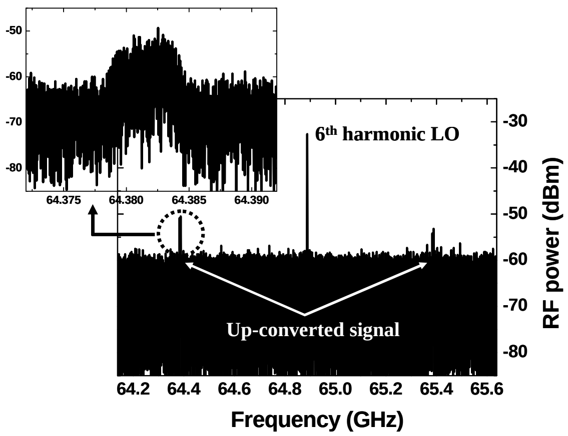

Fig. 6. RF spectrum of up-converted signal into the 6th harmonic frequency band.

Fig. 7(a) and (b) show the down-converted RF spectrum and eye diagram for the demodulated QPSK signal. The eye was clearly opened and the measured error vector magnitude (EVM) was about 15% corresponding to signal to noise ratio (SNR) of 16.5dB.

III. CONCLUSION

In this paper, we have experimentally demonstrated the feasibility of harmonic up-converters based on AML-MS DFB laser. With this proposed scheme, we successfully up-converted 10Mbps QPSK data carried at 500MHz to the 60GHz band corresponding to the 6th harmonic frequency of the fundamental frequency of the AML-MS DFB laser.

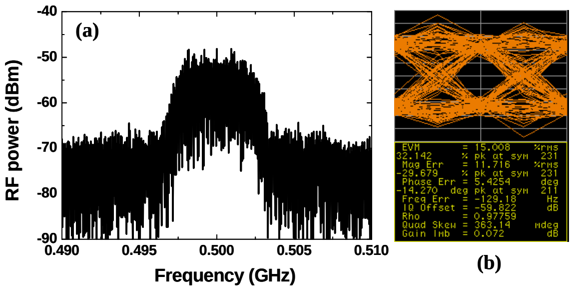

Fig. 7. (a) RF spectrum of the down-converted signal and (b) eye diagram measured by VSA.

REFERENCES

[1] J.-H. Seo, C. –S. Choi, Y. –S Kang, Y. –D. Chung, J. Kim, and W.-Y Choi, "SOA-EAM Frequency Up/Down-Converters for 60GHz Bi-Directional Radio-on-Fiber Systems," *IEEE Trans. Microwave Theory Tech.*, vol. 54, no. 2, pp. 959-966, 2006.

[2] T. Kuri, and K. I. Kitayama, "Long-Term Stabilized Millimeter-Wave Generation Using a High-Power Mode-Locked Laser Diode Module," *IEEE Trans. Microwave Theory Tech.*, vol. 47, no. 5, pp. 570-574, 1999.

[3] Subharmonic Synchronous and Hybrid Mode-Locking of a Monolithic DFB laser Operating at Millimeter-Wave Frequencies," *IEEE Photon. Technol. Lett.*, vol. 9, no. 4, pp. 434-436, 1997.

[4] Y. A. Leem, D. S. Lee, E. D. Sim, S. B. Kim, D. C. Kim, and K. H. Park, "Self-Pulsation in Multisection Laser Diode with a DFB reflector," *IEEE Photon. Technol. Lett.*, vol. 18, no. 4, pp. 622-624, 2006.

[5] Y. Shoji, K. Hamaguchi, and H. Ogawa, "Millimeter-Wave Remote Self-Heterodyne System for Extremely Stable and Low-Cost Broad-Band Signal Transmission," IEEE Trans. Microwave Theory Tech., vol. 47, no. 5, pp.570-574. 1999.