2004 IEEE International Topical Meeting on

Microwave Photonics

Technical Digest

Including Abstracts for **In Search of High-Performance Materials for Microwave Photonics Applications** *Workshop*

4-6 October 2004

The Cliff House Resort & Spa

Ogunquit, Maine

IEEE · MTT-S · IEEE LEOS LASERS & ELECTRO-OPTICS SOCIETY · the photonics center at boston university

IEEE Cat. No: 04EX859C • ISBN 0-7803-8492-X •

Frequency Conversion with Cascaded *SOA-EAM for* Bi-directional Radio-on-Fiber Systems

Jun-Hyuk Seo[1], Chang-Soon Choi[1], Woo-Young Choi[1], Young-Shik Kang[2], Yong-Duk Jung[2], and Jeha Kim[2]

[1]Department of Electrical and Electronic Engineering, Yonsei University, Seoul 120-749, Korea

Tel: +82-2-2123-2874, Fax: +82-2-312-4584, E-mail: wchoi@yonsei.ac.kr

[2]Eletronics and Telecommunications Research Institute, Daejeon 305-350, Korea

Abstract: We experimentally demonstrate frequency up/down-conversion with cascaded SOA-EAM configuration. For frequency up-conversion, SOA cross-gain modulation and photo-detection characteristics of EAM are used and for frequency down-conversion, EAM nonlinearities are used.

I. Introduction

Broadband wireless systems are investigated very actively and fiber-supported wireless systems are attractive because they provide wide bandwidth, easy centralization and low loss transmission [1-6]. To implement these systems successfully, simple and cost-effective base station structures are very important and base stations based on EAM is one of the promising candidates [1, 2]. Because EAM has dual functionalities of photo-detection and signal modulation, it can be used as a simple and cost-effective transceiver.

Previously, we presented the SOA-PD configuration for the remote frequency up-conversion [3]. Using the SOA cross-gain modulation and square-law detection of the photo-detector, data signals are up-converted to the local oscillator (LO) frequency band. By replacing PD with EAM, the same operation is performed and a new functionality of frequency down-conversion can also be obtained due to EAM nonlinearities. With the help of optically generated LO signal, the uplink RF signal is down-converted to the desired intermediate frequency (IF) band at the EAM and modulated to the uplink light source transmitted from central station. Therefore, high frequency electrical mixers are not required for frequency conversion. Fig. 1 shows a system schematic using this SOA-EAM configuration. As shown in the figure, the optical LO signal is wavelength-separated from the data signal channel, so that each base station can share the optical LO signal. Moreover, the system can be easily designed and upgraded with WDM or any other application sources.

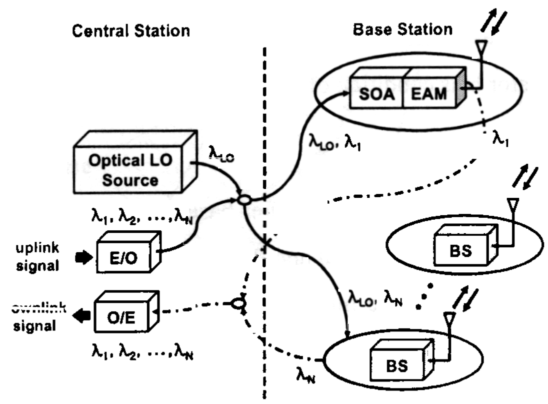

Fig. 1. System schematic with SOA-EAM configuration for the bi-directional link.

II. SOA-EAM Frequency Converter

Fig. 2 shows a simple illustration of photonic frequency up/down-conversion using cascaded SOA-EAM configuration. Fig 2(a) is a frequency up-conversion schematic. The optical LO signal is generated by the optical heterodyne method, which uses two correlated optical modes whose frequency difference is LO frequency. When both optical LO signal and IF data signal are injected into SOA, two optical modes of LO signal are cross-gain-modulated by the IF data signals. The modulated optical LO signal is then photo-detected by EAM and the IF data signals are up-converted to the LO frequency band. This method can be used for the downlink data transmission. Detailed operation characteristics are the same as the SOA-PD frequency up-conversion method and well explained in the reference [3].

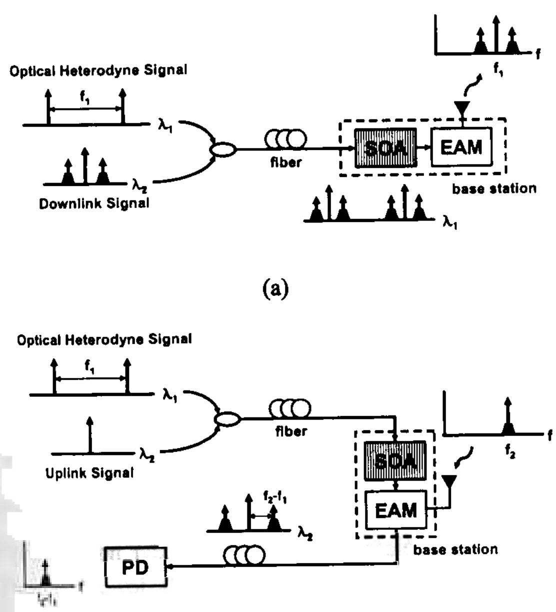

Fig. 2. Cascaded SOA-EAM configuration for frequency up/down-conversion. (a) frequency up-conversion (b) frequency down-conversion.

Fig. 2(b) shows the frequency down-conversion method for the uplink data transmission. With the optically-generated LO signal (f_1) and the uplink RF signal (f_2) modulating EAM, frequency down-conversion is possible. When these two signals modulate the uplink optical signal at EAM, the second order mixing product at frequency f_2-f_1 is generated by EAM nonlinearities. This frequency down-converted signal is transmitted to the central station via uplink fiber without suffering dispersion induced signal suppression problems. The uplink optical source is provided from the central station and downlink optical LO source can be shared for the uplink transmission.

The proposed SOA-EAM frequency up/down converter provides high up-conversion efficiency and compensates the insertion loss of EAM by SOA intrinsic gain. In addition, it makes it possible to perform frequency down-conversion which cannot be realized in SOA-PD. Additional advantages of this scheme are sharing of the optical LO signal and flexible system design. Basically, in this photonic frequency converter, the LO signal and data signal are separated. Therefore, each base station can share the same optical LO signal and systems can be upgraded effectively to the WDM systems or any other applications by changing data sources.

III. Experiment and Results.

Fig. 3 shows the experimental setup for the frequency conversion with the cascaded SOA-EAM. The 25 GHz optical heterodyne LO signal was generated by the double-sideband with a suppressed carrier modulation. The wavelength of the LO signal is 1550 nm. For the downlink IF signal, a 1552.5 nm laser was directly modulated by the 100 MHz signal. These two signals were combined and injected into the SOA for the frequency up-conversion, and then IF modulated LO signal is detected by EAM.

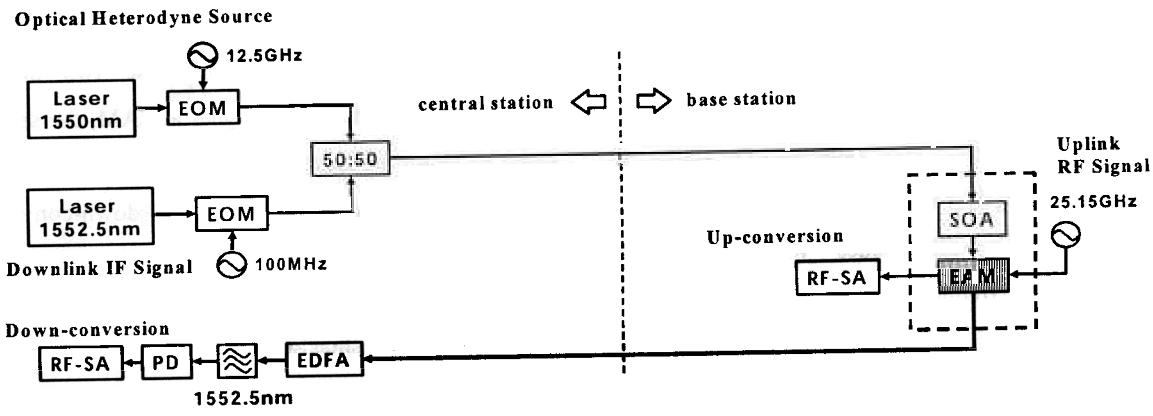

Fig. 3. Experimental setup for the frequency up/down-conversion. EOM : Electro-Optic Modulator, RF-SA : RF-Spectrum Analyzer. EDFA : Eribium-Doped Fiber Amplifier

For the frequency down-conversion experiment, EAM was modulated by the uplink 25.15 GHz RF signal. This signal was down-converted to the 150 MHz signal by the optically generated LO signal and modulated to the 1552.5 nm optical signal that was used for downlink transmission. In the frequency down-conversion experiment, we suppressed the EAM-passed optical LO signal more than 40 dB compared with the uplink optical signal using an optical bandpass filter. The reason to suppress the optical LO signal is that the LO signal which is modulated by the 25.15 GHz signal could generate the optically down-converted 150 MHz signal after photo-detection [4].

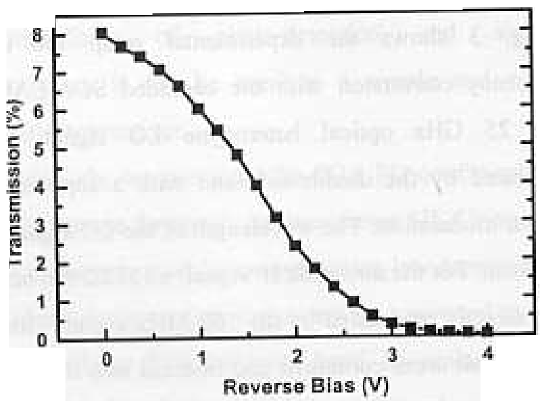

Fig. 4. EAM transmission curve at 1550 nm.

The EAM used in this experiment is a polarization insensitive multiple-quantum well traveling-wave electroabsorption modulator [5]. This was designed and optimized for the 40Gbps modulation. Fig. 4 shows the transmission characteristics of the used EAM at 1550 nm. The insertion loss at 0V bias is about 10 dB.

Fig. 5(a) shows the frequency up-converted spectrum. As shown in the figure, 100 MHz IF signal is up-converted to the 25 GHz LO frequency band. Fig 5(b) shows the frequency down-converted spectrum that clearly shows the down-converted 150 MHz signal.

To investigate the down-conversion characteristics, we also measured the dependence of the down-converted signal power on the EAM bias voltage. Fig. 6 shows the measured down-converted signal power according to the EAM bias voltage. This bias dependence is related to the second order nonlinearity characteristics of the EAM.

IV. Conclusion

The cascaded SOA-EAM configuration is proposed for the bi-directional radio-on-fiber systems. With this scheme, remote frequency up-conversion using the

SOA cross-gain modulation and frequency down-conversion using the EAM nonlinearity are simultaneously achieved. We showed that 100 MHz downlink signal was up-converted to the 25 GHz band, and 25.15 GHz uplink signal was down-converted to 150 MHz. These results demonstrate that a simple and cost-effective base station can be implemented without high frequency electrical mixers.

We also investigated the down-converted signal power according to the EAM bias voltages, which follows the second order nonlinear characteristics of the EAM.

V. References

[1] A. Stöhr, K. Kitayama, and D. Jäger, "Full-Duplex Fiber-Optic RF Subcarrier Transmission Using a Dual-Function Modulator/Photodetector", *IEEE Trans. Microwave Theory Tech.*, vol. 47, no. 7, pp. 1338-1341, July 1999.

[2] L. Noël, D. Wake, D. G. Moodie, D. D. Marcenac, L. D. Westbrook, and D. Nesset, "Novel Technique for High-Capacity 60 GHz Fiber-Radio Transmission Systems", *IEEE Trans. Microwave Theory Tech.*, vol 45, no. 8, pp. 1416-1423, Aug. 1997.

[3] Y.-K. Seo, C.-S. Choi, and W.-Y. Choi, "All Optical Signal Up-Conversion for Radio-on-fiber Applications Using Cross-Gain Modulation in Semiconductor Optical Amplifiers", *IEEE Photon. Technol. Lett.*, vol. 14, no. 10, pp. 1448-1450, Oct. 2002.

[4] T. Kuri, K. Kitayama, and Y. Ogawa, "Fiber-Optic Millimeter-Wave Uplink System Incorporating Remotely Fed 60-GHz-Band Optical Pilot Tone", *IEEE Trans. Microwave Theory Tech.*, vol. 47, no. 7, pp. 1332-1337, July 1999.

[5] J. Lim, Y.-S. Kang, K.-S. Choi, J.-H. Lee, S.-B. Kim, and J. Kim, "Analysis and Characterization of Traveling-Wave Electrode in Electroabsorption Modulator for Radio-on-Fiber Application", *J. Lightwave Technol.*, vol. 21, no. 12, pp. 3004-3010, Dec 2003.

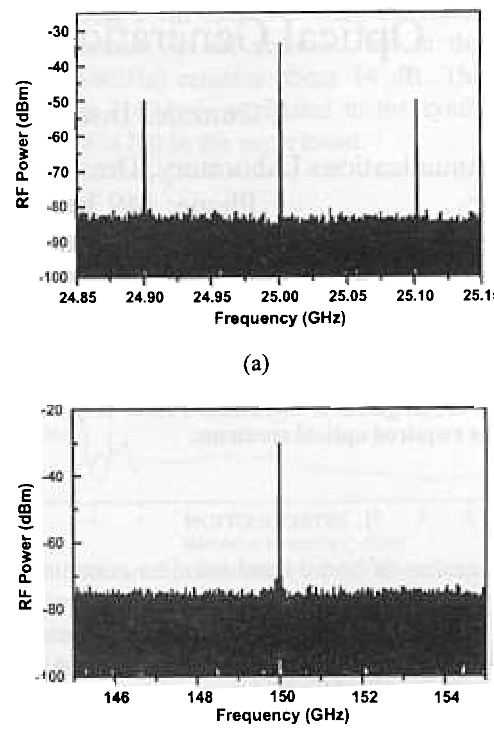

Fig. 5. RF Spectrum for the frequency up-conversion (a) and the frequency down-conversion (b).

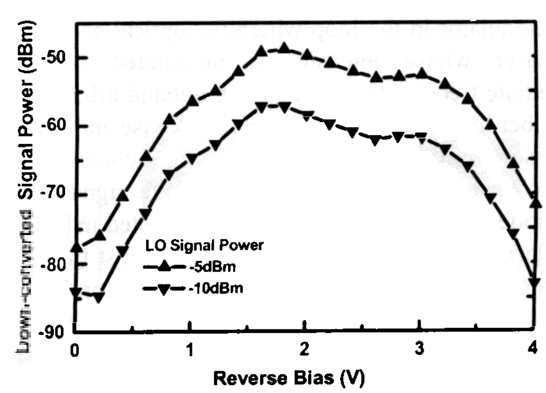

Fig. 6. The dependence of the down-converted signal power on the EAM bias voltages.