LONG WAVELENGTH VCSEL POTENTIAL FOR PROCESSING OF ANALOG MICROWAVE SIGNALS

V. Iakovlev[1], M. Belkin[2], L. Belkin[2], G. Suruceanu[3], A. Mereuta[3], A. Caliman[3], A. Sirbu[1], and E. Kapon[1]
[1]Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland; [2]Moscow State Technical University of Radio-Engineering, Electronics and Automation, Moscow, Russian Federation; [3]BeamExpress SA, 1015 Lausanne, Switzerland
vladimir.iakovlev@epfl.ch

Abstract. *A VCSEL-based optoelectronic frequency conversion process is investigated in details by simulation in modern OE-CAD tools and experimentally. A novel version of a VCSEL based microwave frequency converter is proposed. An example of cost-effective application for promising telecom networks is highlighted as well.*

Keywords: *microwave photonics, vertical cavity surface emitting laser, optoelectronic frequency converter.*

I. Introduction

Long wavelength vertical cavity surface emitting lasers (VCSELs) are becoming increasingly attractive for different photonics applications thanks to well-known engineering and cost benefits [1]. As one of remarkable photonics branch - the microwave photonics technique is becoming the most promising approach to overcome the basic frequency limits of active microwave semiconductor devices, there is an interest to evaluate the potential of long wavelength VCSELs for processing of microwave signals in general, and in particular for Radio over Fiber (RoF) technology [2].
Modern R&D works in the field of microwave photonics is focused on the features provided for efficient photonic-based oscillation and conversion of microwave signals [3]. Generally, generation of microwave-band mixing products is based on the non-linear conversion features of different optoelectronic devices [4]. As of today, non-linear conversion is performed in several optoelectronic mixer architectures employing external modulation of electro-optic modulator [5], semiconductor optical amplifier [4], and a combination of these components [3, 4]. Common drawbacks of these devices are high cost and low conversion efficiency as compared with electronic counterparts. Our analysis of the above publication reveals that in the case of RoF applications the most parametric/cost-effective technique is direct intensity modulation of semiconductor laser, especially when a low cost emitter as VCSEL is used. Details of our simulation and test of VCSEL-based optoelectronic frequency converter (OEFC) and a novel version of OEFC titled optoelectronic frequency multiplicator (OEFM) are reported in [6]. In this paper, we review our previous results and present some novel ones referred to detailed experimental study of OEFC and OEFM features in microwave band and an example of OEFM application for promising telecom networks.

II. The long wavelength VCSEL features

Long wavelength wafer-fused VCSELs of 1310 nm manufactured by Beam Express, SA, Lausanne were used in this work. The active cavity includes an InAlGaAs/InP multi-quantum well region with four to six compressively strained quantum wells and a p++/n++ InAlGaAs tunnel junction. The InP-based active cavity and GaAs-based distributed Bragg reflectors (DBRs) are grown by low pressure metal-organic vapor phase deposition (LPMOVPE) on 2-inch (100) wafers. A mesa-structure of 6–7 μm in diameter formed in the tunnel junction that is re-grown with n-type InP serves for carrier and photon confinement. Electrical contacting is performed by the top and bottom intra-cavity n-InP layers. This contacting scheme allows using undoped top and bottom DBR mirrors. InGaAsP cavity adjustment layers that are located on both sides of the active cavity serve for precise adjustment of the emission wavelength. The optical confinement is due to a lateral refractive index variation. The typical VCSEL parameters that we used in our simulation: threshold current is 2 mA; small-signal relaxation frequency is 2.5 GHz at bias current of 3.2 mA increasing up to 6 GHz at larger currents. More detailed description of VCSEL's design, fabrication process and performances are reported in [1].

III. Example of OEFM application for FiWi networks

Hybrid Fiber-Wireless (FiWi) access telecom network based on Radio-over-Fiber (RoF) technology is a novel backhaul network architecture that integrates the next-generation WLAN-based wireless mesh network and Ethernet passive optical network (EPON). Its major feature lies in squeezing the cell diameters up to picocell (10m - 200 m) or femtocell (10 cm – 10 m) [2]. As a result the base station equipment must satisfy extremely rigid requirements related to the cost-effectiveness. To meet this issue we propose to use OEFM in the base station's uplink channel that is much simpler than known method of remote delivery of a reference oscillator signal. Figure 1 shows an example of X-band uplink circuitry realization by the OEFM. The rest elements of the layout are: 1 - receiving antenna, 2 – sub-harmonically pumped mixer, 3 – IF filter, 4, 8 – amplifiers, 5 – coupler, 6 – uplink laser, 9 – carrier recovery unit.

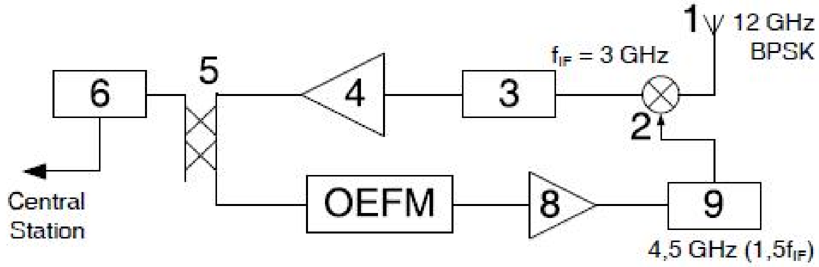

Fig. 1. Example of OEFM application in uplink channel of FiWi network

IV. Conclusion

In this paper we presented a detailed investigation of potentially low cost VCSEL-based optoelectronic frequency converter and novel sub-harmonic frequency multiplicator for the circuitry of RoF's systems. VCSEL based microwave photonics devices have a potential for the application in future equipment for ultra-wide band telecom and radar systems (for example, in passive location) and in measurement techniques. The work is in progress for decreasing conversion losses in these devices.

V. References

1. E. Kapon, A. Sirbu, "Power-efficient answer," Nature Photonics, vol. 3, pp. 27-29, Jan. 2009.
2. M. Sauer, A. Kobyakov, J. George, "Radio over Fiber for Picocellular Network Architectures," IEEE J of Lightwave Technol., vol. 25, no. 11, pp. 3301-3320, Nov. 2007.
3. J. Yao, "Microwave Photonics," IEEE J of Lightwave Technol., vol. 27, No 3, pp. 314-335, Febr. 2009.
4. B. Cabon, Y. Le Guennec, M. Lourdiane, and G. Maury, "Photonic mixing in RF modulated optical link," in LEOS 2006, Oct. 2006, pp. 408-409.
5. A. C. Lindsay, G. A. Knight, and S. T. Winnall, "Photonic Mixers for Wide Bandwidth RF Receiver Applications," IEEE Trans. on MTT, vol. 43, No 9, pp. 2311-2317, Sept. 1995.
6. M. E. Belkin, L. M. Belkin, A. V. Loparev, V. Iakovlev, G. Suruceanu, A. Mereuta, A. Caliman, A. Sirbu, and E. Kapon. Microwave-Band Optoelectronic Frequency Converters Based on Long Wavelength VCSELs. IEEE COMCAS-2011, Tel Aviv, 7-9 November, 1P1-6, p. 1-5.