A Survey on Optical Millimeter Wave Generation using Frequency Multiplication based on External Modulation

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Abstract- *A novel method to generate an optical millimeter-wave signals with carrier suppression by using frequency multiplication based on external modulation technique. In this paper using the approach to achieve frequency multiplication using two cascaded Mach-Zehnder modulators (MZMs). By generating optical millimeter wave signal using this technique has been considered as the effective solution for the high frequency. A theoretical analysis that leads to the conditions for achieving frequency quadrupling, sextupling, octupling and 12-tupling is developed. And the system performance is achieved by noise performance, bit error rate value, tunability and stability.*

Keywords- Mach-Zehnder modulator (MZM), optical millimeter wave, radio over fiber

I. INTRODUCTION

For high speed internet access and mobile multimedia services wireless broadband networks are needed. These services require the bandwidth higher than 2mbps per radio channel. To serve this purpose higher microwave bands and millimeter wave bands are allocated. The radio over fiber system is efficient to provide these broad band services to the mobile customers with high capacity. ROF is the analog transmission system which distributes the radio waveform, directly at the carrier frequency from a Central Station (CS) to Base Station (BS) via optical fiber. The analog signal that is transmitted over fiber is either Intermediate Frequency (IF) signal or baseband signal. For both the cases additional hardware for up converting it to Radio Frequency (RF) band is required at the BS.

Millimeter wave corresponds to the radio spectrum between 30 GHz to 300 GHz, with wavelength between one and ten millimeters. In wireless communication, the term generally corresponds to a few bands of spectrum near 38, 60 and 94 GHz, and more recently to a band between 70 GHz and 90 GHz (also referred to as E-Band), that have been allocated for the purpose of wireless communication in the public domain. With the development of human society, people have higher requirements for the services, such as video, multimedia and other new value-added services. To offer these broadband services, wireless systems will need to offer higher data transmission capacities.

The generation and transmission of millimeter or microwave signals transmitted over an optical fiber had been investigated for various applications including broad band wireless access networks, optical sensors, phase array antennas, antenna remoting and radar applications. The millimeter wave signal generation in electrical domain is very difficult. So that the millimeter wave signals are generated here in optical domain. In general the generation techniques have been divided into three techniques. First technique including optical injection locking, the second technique is optical phase-locked loop and the third technique is external modulation [1].

In this paper the generation of a millimeter wave signal can be done by using external modulation. And the advantage of using this technique is simplicity of the system, frequency tunability and stability. Here the two cascaded MZMs are biased at the maximum transmission point to generate the frequency doubling of the signal. That is it can eliminate the first order side bands. Then only the second order side bands are present at the output of the MZM. The two side bands are beating at the photo detector(PD) that generate the millimeter wave signal having the frequency that is twice that of the RF driving signal.

By achieving a higher multiplication factor including frequency quadrupling, sextupling, octupling, 12-tupling signals are implemented by biasing the MZMs are at the maximum or minimum transmission point with the use of an optical phase shifter and an optical fiber. By using this technique having the advantage of the system is simple with high frequency tunability and stability [2].

II. CONCEPTS AND EXPERIMENTAL SETUP

A. Frequency Quadrupling

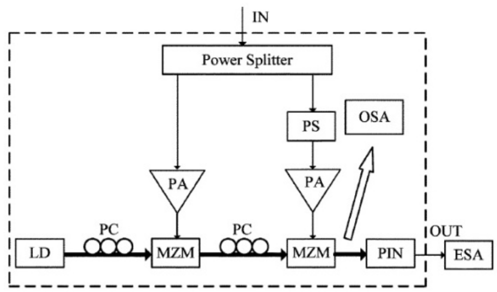

Fig.1 Schematic diagram for frequency quadrupling system

LD-laser diode, PC- polarization controller, OSA- optical spectrum analyzer, ESA-electrical spectrum analyzer, PIN-pin diode.

The setup for the frequency quadrupler using external modulation is shown in Fig.1. A continuous wave laser source is applied to the two cascaded MZM modulators using two polarization controllers. And the driving signal is directly applied to the MZM modulator, which is biased to completely suppress the even order optical sidebands. Here only the first order sidebands are considered. Then they are modulated by the same signal with the phase difference of φ in the modulator, which is biased to completely suppress the even order sidebands including the carrier. Then the obtaining signal having second order sidebands only [3].

B. Frequency Octupling

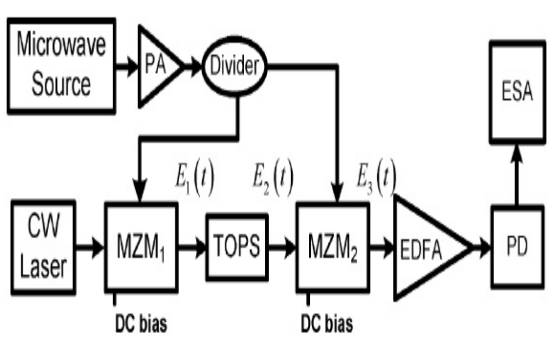

Fig.2. Schematic diagram for frequency octupling system

EDFA- erbium doped fiber amplifier, ESA- electrical spectrum analyzer.

The setup for the frequency octupling system is shown in Fig.2. It consist of a continuous wave laser source and two MZMs that are connected to the tunable optical phase shifter (TOPS) and a photo detector. The lowest input frequency signal from a source is amplified by the power amplifier (PA), and the signal is divided into two by a power divider and that signal is applied to the two MZMs. Both MZMs are biased to suppress the odd order sidebands. And by properly adjusting the phase shift introduced by the TOPS and the power of the driving RF signal only the fourth order sidebands are generated. By beating the fourth order sidebands at the PD, the frequency octupled signal is generated [4].

C. Frequency 12-tupling

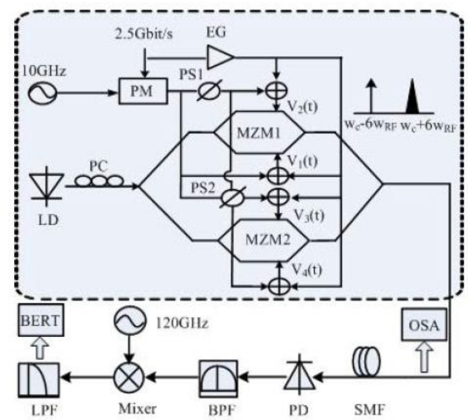

Fig.3. Schematic diagram for frequency 12-tupling system

LD- laser diode, PC- polarization controller, PM- phase modulator, EG- electrical gain, PS- phase shifter, SMF- single mode fiber, BPF-band pass filter, OSA- optical spectrum analyzer, BERT- bit error ratio tester.

The setup for frequency 12-tupling system is shown in Fig.3. The light emitted from the laser source is injected into the integrated nested MZM that is the two MZMs are connected in parallel. The two MZMs are biased at the minimum transmission point. The phase shift between the two phase shifters is π and $\pi/2$.The generated optical millimeter wave signal having sixth order sidebands only. The generated millimeter wave signal having the frequency multiplication of twelve times of the RF driving signal [5].

III. RESULTS AND DISCUSSION

In the first experiment a continuous wave laser source is applied to the two cascaded MZMs via two PCs. The two modulators having the bandwidth of more than 10GHz are biased to suppress the carrier. The Fig. 4(a) shows the optical spectrum at the output of the first modulator. And the phase difference is adjusted by $\pi/2$. Then only the second order sidebands are considered. Fig. 4(b) shows the second order optical sidebands these are 20db larger than the others.Fig.5 shows the electrical spectrum of the generated signal at the output of the pin diode having the bandwidth of 40GHz.

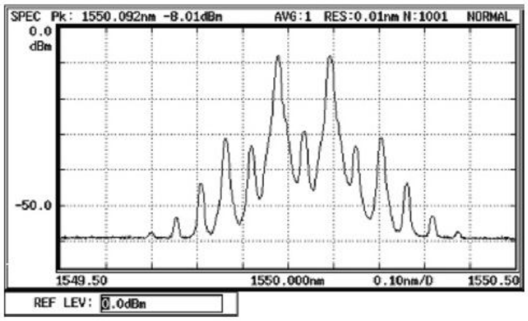

Fig.4 (a) Optical spectrum at the output of the first Modulator

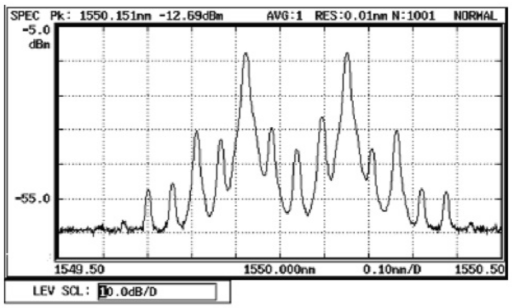

Fig .4(b)Optical spectrum at the output of the second modulator

In the second experiment the polarization modulation index is set to 1.699 therefore, the optical carrier signal is eliminated. The optical spectrum of the signal at the MZM and the electrical spectrum at the output of the PD are shown in Fig.5. Here the frequency octupled signal is generated due to the incomplete suppression of the other side bands, the powers of the harmonic signals are high. In a frequency octupled component has a 10.5 db greater than the next largest component that is seventh harmonic signal.

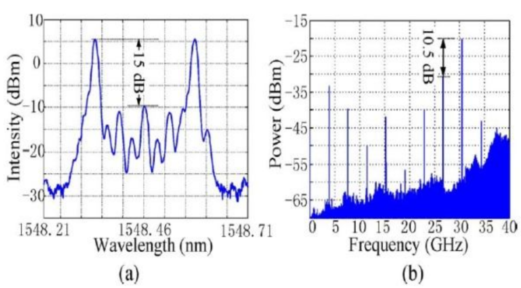

Fig.5.Measured Optical and Electrical spectrum of the generated octupled signal

In a third experiment the frequency 12- tupling optical millimeter wave signal is generated. And the scheme is developed based on a nested MZM to overcome chromatic dispersion without any optical filter. By properly adjusting the direct current bias voltages of the MZMs, the modulation voltage, the output signal having only two sixth order sidebands and the baseband data is only modulated on one sideband. And the signal is transmitted over the fiber having no periodical fading and bit walk-off effect caused by the chromatic dispersion. Fig.6. shows the spectrum of the frequency 12- tupling optical millimeter wave carrying only sixth order sidebands. When compare the other two techniques this can provides the good transmission performance.

IV. CONCLUSION

A novel approach for generating Optical millimeter wave signals using frequency multiplication based on external modulation. The theoretical analysis is performed, including the phase condition and the bias adjustment, to achieve the frequency quadrupling, octupling, and 12-tupling. And the performance of the system in terms of noise performance, frequency tunability, and stability are evaluated. An important application of this technique is to generate a high frequency signal using a low frequency input.

REFERENCES

[1] Jianping Yao, ”A Tutorial on Microwave Photonics”, IEEE photonics society news letter, April 2012.

[2] Wangzhe Li and Jianping Yao,”Investigation of Photonically Assisted Microwave Frequency Multiplication Based on External Modulation”, IEEE transcations on microwave theory and technologies, VOL,58,No.11, November 2010

[3] Jian Zhange, Minghua Chen, Tianliang Wang and Shizhong Xie, ”A Photonic Microwave Frequency Quadrupler Using Two Cascaded Intensity Modulators With Repetitious Optical Carrier Suppression”,IEEE photonics technology letters, VOL.19, No.14, July 15, 2007.

[4] Wangzhe Li and Jianping Yao,”Microwave Generation Based on Optical Domain Microwave Frequency Octupling”, IEEE photonics technology letters, VOL.22, No.1, January 1, 2010.

[5] Zihang Zhu, Shanghong Zhao, Yongjun Li, Xingchun chu, Xiang Wang and Guhao Zhao, “A Radio-over-Fiber System with Frequency 12-TuplingOptical Millimeter wave Generation to Overcome Chromatic Dispersion”, IEEE journal of Quantum Electronics, VOL. 49, No.11, November 2013.