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Improvement of Optical Millimeter Wave by Dual-parallel $LiNbO_3$ Modulator and ALC-EDFA

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Abstract By using an improved $LiNbO_3$ modulator, it is possible to generate large second order harmonics with a lower carrier to noise ratio, leading to the production of an significantly improved optical millimeter wave. Furthermore, it is possible to improve the frequency characteristic of the optical millimeter wave by using an automatic level control amplifier.

Keywords $LiNbO_3$ modulator, Optical millimeter wave, Two-tone light wave signal, Radio over fiber

1. Introduction

Optical millimeter wave generation by using a $LiNbO_3$ modulator in a Mach-Zehnder configuration is well known [1]. In this paper, it is reported that an optical millimeter-wave generator with a newly developed $LiNbO_3$ modulator could be improved in several aspects.

1.1 Dual- Parallel $LiNbO_3$ Modulator

The developed modulator has been improved from a conventional modulator in the following points.

1) The V-pi voltage is approximately half.
2) The frequency response S21 has been improved.
3) The laser damage resistance is enhanced.

If the V-pi is small, the modulator can be driven by a small RF power. Therefore, it is possible to generate a larger harmonic from a small RF power. Since a larger RF amplifier output power is usually expensive, a small V-pi is useful [2].

The frequency response of the conventional modulator is about 15 GHz. In the case of the improved modulator, it has been extended to more than 25 GHz [2].

Research and development of fibers for the W-band (75—110 GHz) is quite active. Furthermore, the modulator input frequency corresponds to a quarter of the frequency of the millimeter light wave. In the conventional modulator, because it was usually developed for 10 GHz, the frequency response reaches some limitations. The frequency response of the developed modulator has been expanded to more than 25 GHz. It is ideal for generating a W-band millimeter wave.

Optical input power of the conventional modulator is usually 10 dBm. The insertion losses of the modulators are about 5 dB, however the output power of the harmonic is much smaller. In applications such as Radio-Over-Fiber, the required output power of the modulator should be high, leading to a better carrier to noise ratio for the system. The input resistance of the improved modulator is not clearly defined, although we could apply 17 dBm to the developed modulator.

1.2 Two-tone Signal Generator

To generate the W-band optical millimeter wave, the RF signal must be quadrupled. By controlling the modulator DC bias, it is possible to minimize the primary sidebands. In order to detect primary sideband, a thermally controlled FBG (Fiber Bragg Grating) was used. The modulator in a dual parallel configuration is constituted by three Mach-Zehnders. The three Mach-Zehnders are controlled sequentially. In order to reject the large zero-order light left at the output of the modulator, it is rejected by an optical notch filter is used.

1.3 ALC-EDFA

In Radio-Over-Fiber applications, the optical power required is greater than the output power of the modulator. Moreover, the level of the optical millimeter wave generated by the modulator is not constant. By using

Fig. 1 Two-tone signal generator.

an ALC (auto level control) amplifier, it is possible to amplify the optical millimeter wave while keeping the output power constant.

Previously, we have developed a variable optical attenuator with a PMN-PT piezoelectric element shown as Fig. 3 [3]. For the amplifying element, an EDFA (Erbium-Doped optical Fiber Amplifier) is used.

In order to control the output pump light, the amplifier can be monitored by tapping the input signal. The attenuator is controlled by monitoring the output power. It can be controlled precisely by a FPGA (Field-Programmable Gate Array) in order to avoid that the EDFA is saturated, leading to an optimal noise figure [4].

2. Effect of Developed Modulator

Fig. 4 shows the second order harmonic power as a function of the RF input power of the modulator. The RF input power of the modulator is 22 dBm. The second order harmonic output power of the improved modulator could become about 20 dB greater than the conventional product. Within this output power improvement, 10 dB is due to the light source power improvement. In the vicinity of the current operating point, a variation of 1 dB in the RF input power corresponds to a 2 dB change in the second order harmonic output power. Therefore, 5 dB is due to the improvement of the V-pi voltage and the frequency characteristics.

Fig. 5 shows a spectrum of the optical millimeter wave. Because the output power of the modulator is increased, the amplified signal C/N ratio could be improved by 20 dB.

Fig. 2 Automatic level control EDFA.

Fig. 3 Variable optical attenuator.

3. Effect of the ALC-EDFA

Fig. 6 shows the frequency response of the optical millimeter wave. The frequency response at the output of the modulator is not flat. This is due to the frequency response of the modulator input signal that is not flat. Because of the high frequency, the slope characteristics of the coaxial cable cannot be ignored. A standing wave due to the impedance matching between high-frequency devices also occurs. The ALC-EDFA can adjust the frequency response.

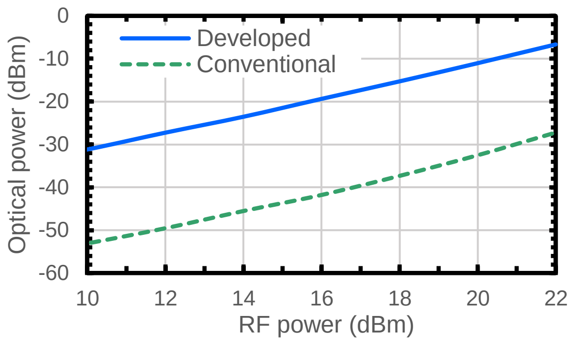

Fig. 4 The second harmonic level.

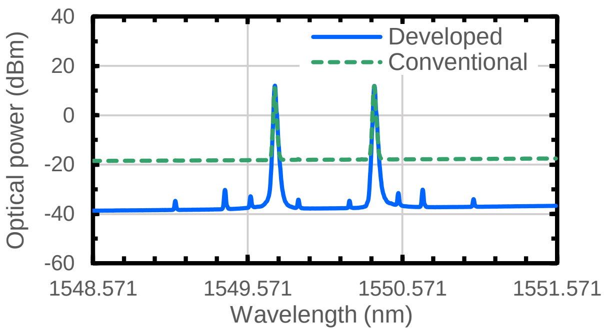

Fig. 5 Optical millimeter wave (80 GHz).

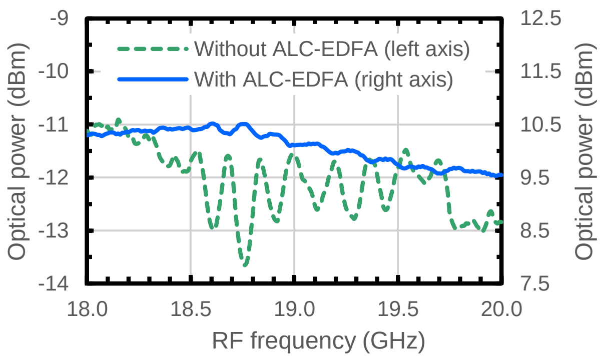

Fig. 6 Frequency response.

4. Conclusion

The optical millimeter-wave signal using a dual-parallel $LiNbO_3$ modulator, including a carrier wave generated in the W-band could be realized. Various applications can also be expected. The signal C/N ratio as well as its flatness could be improved due to the optimized modulator.

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