applied optics

Filterless 16-tupling photonic millimeter-wave generation with Mach–Zehnder modulators using remodulation

Aasif Bashir Dar* **and Faroze Ahmad**

Department of Electronics and Communication Engineering, IUST Awantipora, 192122, Jammu and Kashmir, India
**Corresponding author: daraasifshzd@gmail.com*

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An optical millimeter-wave generation technique is presented in this paper. The system's two frequency quadruplers use dual-parallel Mach–Zehnder modulators. A 5 GHz radio frequency signal is fed to a quadrupler, which yields a 20 GHz signal after detection using a photodiode. The detected signal is used for remodulation of the other quadrupler, resulting in an 80 GHz signal with an optical sideband suppression ratio of 28 dB and a radio frequency spurious sideband suppression ratio of 27 dB. Further, the effect on the system performance in terms of the optical sideband suppression ratio and radio frequency spurious sideband suppression ratio with variation of various parameters is also evaluated. The optical sideband suppression ratio is well above 14 dB for a phase offset of ±9° in phase shifters with a modulation index range of 1.5–3.5 and an amplifier gain range of 25 dB to 32 dB. © 2020 Optical Society of America

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1. INTRODUCTION

Next-generation wireless technologies are aimed to provide unprecedented ultrahigh-speed data connectivity to mobile users. Spectral congestion at microwave frequency bands encouraged the use of millimeter-wave (mmWave) frequency bands in 5G and beyond [1]. Further, wireless access network (WAN) operating at mmWave bands offer high speed indoor/outdoor mobile connectivity. mmWave technology together with radio-over-fiber (ROF) provide seamless convergence between radio and optical signals [2]. Due to restricted frequency response, electronic devices cannot be used to generate higher frequencies economically. Therefore, photonic mmWave generation has become a hot research topic in recent years.

Different techniques for mmWave generation have been proposed, such as optical heterodyne [3], four-wave mixing (FWM) [4], stimulated Brillouin scattering (SBS) [5,6], direct modulation [7] and external modulation. As two optical sources are incoherent, the optical heterodyne approach results in a radio frequency signal with a relatively high phase noise. FWM and SBS techniques result in bulky systems and have limited frequency multiplication factors (FMFs). mmWave generation using Mach–Zehnder modulators (MZMs) offers higher reliability, FMF, and frequency tunability. Photonic mmWave generation employing quadrupling [8,9], sextupling [10], octupling [11–14], 12-tupling [15,16], and 16-tupling [17] have been demonstrated. In [18], frequency-octupling using two incoherent optical sources employing improved feedforward modulation (IFFM) to reduce phase noise has been proposed. The modulation index can bet set in the range between 1.00 to 3.84, resulting in a low-cost and easy implementation. In 2019, Wang *et al.* proposed a scheme of 16-tupling mm Wave generation using only two MZMs and optical attenuators (OATT) [19]. Optical attenuators are finely tuned so as to suppress the zeroth-order optical band. MZMs are operated at a relatively higher modulation index of 7.59. The optical sideband suppression ratio (OSSR) is above 15 dB for a smaller modulation index range of 7.45–7.7.

In this paper, we propose mmWave generation using remodulation for the first time, to the best of our knowledge. The proposed system employs two similar frequency quadruplers. A detected signal at the output of one quadrupler acts as a remodulating signal for other quadrupler. System performance with variation of different parameters is also analyzed. Compared to [19], our proposed system operates at a lower modulation index and the OSSR is above 15 dB for a very large modulation index range of 1.5–3.6. The paper has four sections. The principle of quadrupling and 16-tupling is discussed in Section 2. The results are discussed in Section 3, and the conclusion is presented in Section 4.