Millimeter-wave Harmonic Frequency Up-Conversion Using Selective Sideband Brillouin Amplification

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Abstract: Using selective sideband Brillouin amplification induced in standard single-mode fiber, we successfully demonstrate harmonic frequency up-conversion of 10Mbit/s QPSK data carried by 1.55GHz intermediate frequency into 30GHz band with larger than 20dB RF gain.

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1. Introduction

Recently, millimeter-wave radio-over-fiber (RoF) systems have been actively investigated because low-loss and wide-bandwidth characteristics of fiber allow the realization of flexible and cost-effective millimeter-wave wireless networks [1]. For such applications, it is desired that all of the complex signal processing steps such as millimeter-wave generation and frequency up-conversion are done in a central station (CS) so that antenna base stations (BSs) can be realized in a compact and cost-effective manner. Selective sideband Brillouin amplification (SSBA) based on stimulated Brillouin scattering (SBS) induced in optical fiber can provide a good solution since it can perform harmonic millimeter-wave generation and frequency up-conversion in CS. Previously reported techniques require an additional pumping source whose lasing frequency should be accurately controlled to amplify the desired optical sideband with narrow SBS gain bandwidth (~15MHz) [2-3]. In this paper, we demonstrate that millimeter-wave up-conversion can be achieved by beating of optical sidebands, separated by the desired frequency, one of which is Brillouin amplified. Our approach provides high RF gain without an additional pumping source, even if a low-speed Mach-Zehnder modulator (MZM) is utilized. We successfully demonstrate up-conversion of 10Mbit/s QPSK data carried by 1.55GHz intermediate frequency (IF) signal into 30GHz band with larger than 20dB RF gain.

2. Experimental set-up and Measurement Results

Fig.1 shows the experimental set-up used for our study. The optical carrier at λ =1551.35nm provided by a tunable laser source is divided into two arms by an optical coupler. In one arm, the optical carrier is modulated by RF signal having the same frequency as the Brillouin frequency (f_B=10.85GHz) as well as 10Mbit/s QPSK data signals carried by 1.55GHz f_{IF}. Several optical sidebands separated by f_B and f_{IF} from the optical carrier are generated by MZM nonlinearity. Theses signals are injected into 10km long SSMF. In the other arm, the optical carrier is sufficiently amplified to be used as a pumping source for SSBA. The amplified carrier is injected into SSMF via an optical circulator and propagates in the opposite direction to the modulated signals. The polarization of the amplified carrier is adjusted by a polarization controller. The optical spectra in front of PD are shown in Fig. 1. As can be seen in the figure, the 1st sideband located at longer wavelength from the optical carrier is amplified by SSBA. When detected in PD, these signals perform harmonic up-conversion due to mode beating. We are interested in the beating of the amplified sideband and the 2nd sideband signal located at shorter wavelength from the optical carrier for up-conversion into the millimeter-wave band.

Fig. 2 shows measured optical spectra before PD for two cases: one without any SSBA (Fig.2 (a)) the other with 10dBm optical pumping in 10km long SSMF (Fig.2 (b)). Fig. 2(b) clearly shows that the 1st sideband is amplified by

SSBA, although the resolution (0.07nm) of the optical spectrum analyzer was not high enough to distinguish each sideband. Fig. 3 (a) shows RF gain determined by the power ratio of the RF signals measured with and without SSBA as a function of the optical pumping power, and Fig. 3(b) shows RF spectra of harmonic up-converted 10Mbit/s QPSK data signal (lower sideband) around 30GHz with SSBA. As shown in the figure, lager than 20dB RF gain can be obtained with 10dBm optical pumping.

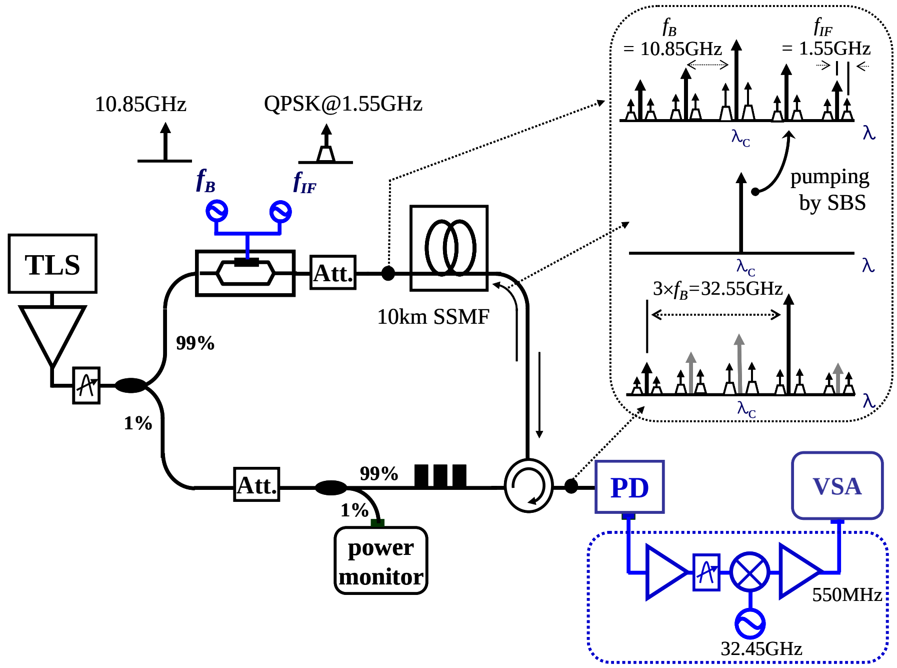

Fig. 1. Experimental setup for harmonic up-converters based on SBS. (TLS: Tunable laser source, Att.: Attenuator, VSA: Vector signal analyzer)

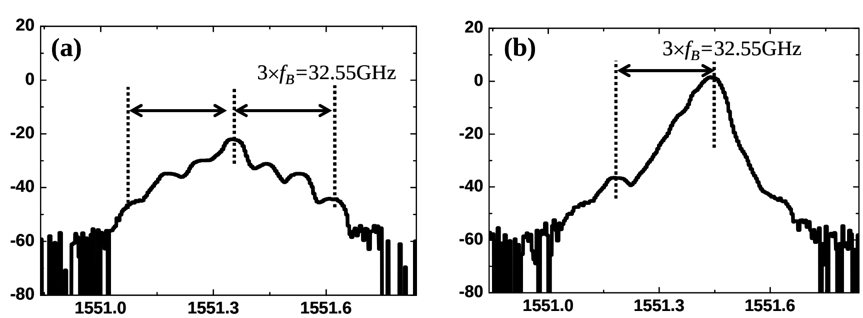

Fig. 2. Measure optical spectra (a) in case of no SSBA and (b) after SSBA induced by 10dBm optical pumping

In order to evaluate the up-converted data quality more accurately, up-converted data were electronically down-converted to 550MHz IF band as shown in Fig. 1. Fig. 4 shows the down-converted data spectrum as well as eye diagram for demodulated 10Mbit/s QPSK signal. The eye is clearly open, and the error vector magnitude (EVM) of about 12.9% is obtained.

3. Conclusions

We demonstrated millimeter-wave harmonic up-conversion using SSBA in 10km long SSMF. 10Mbit/s QPSK data carried by 1.55GHz IF signal were successfully up-converted to 30GHz millimeter-wave band corresponding to the 3rd harmonic of f_B with larger than 20dB RF gain. We believe this scheme can be useful for the construction of cost-effective millimeter-wave radio-over-fiber systems.

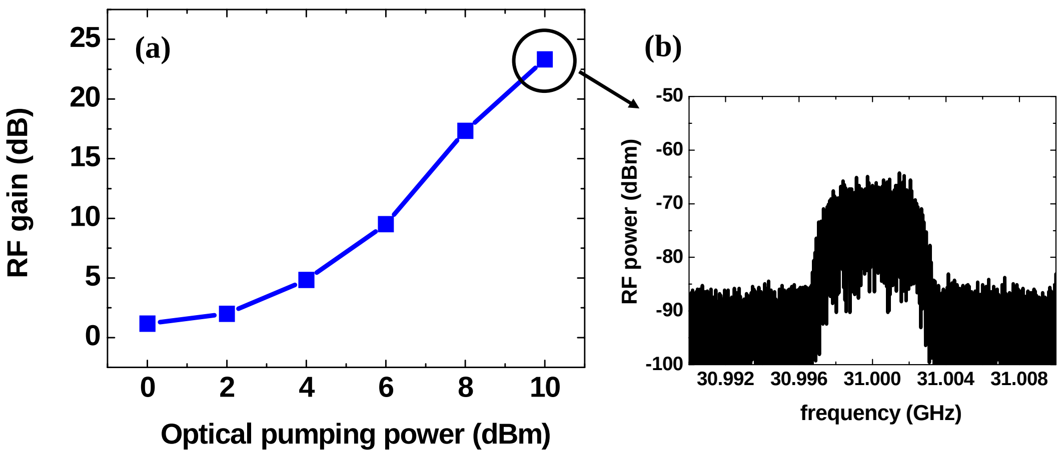

Fig. 3. Measured RF gain according to the optical pumping power (a) and up-converted RF spectra (lower sideband) in the case of 10dBm optical pumping power (b).

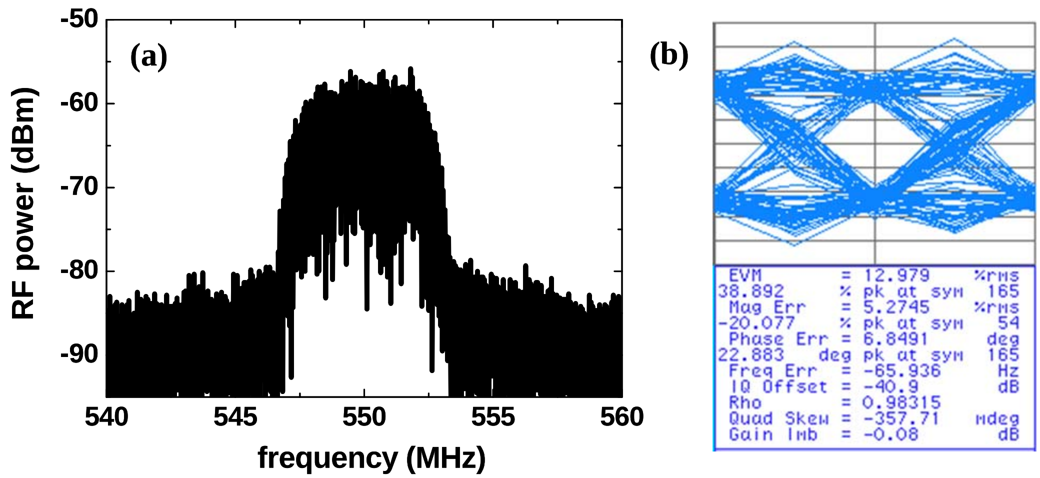

Fig. 4. Measured RF spectra of the down-converted QPSK signal (a) and the eye diagram of the demodulated QPSK signal (b).

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