반도체 광 증폭기의 상호 이득 변조를 이용한 전광 주파수 상향 변환
All-optical signal up-conversion using cross-gain modulation in semiconductor optical amplifier

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Abstract

We present a novel scheme of mixing optical intermediate frequency (IF) signals with optical local oscillator (LO) signals using cross-gain modulation in a semiconductor optical amplifier. This scheme provides high conversion efficiency and is independent of the incident light wavelength and polarization. It can be useful for radio-on-fiber transmission system applications in which one remote LO signal is provided for several WDM IF signals.

I. Introduction

The fiber-optic transmission of radio signals has attracted much attention for broadband radio access system applications because it allows centralization of complex equipment at one central office and simplification of base stations [1-4]. For the increase of the total data traffic capacity, the WDM technique can be introduced to the millimeter-wave-over-fiber systems [1-2], in which WDM data signals were up-converted to the millimeter-wave frequency using one Mach-Zehnder modulator (MZM). However, this technique has several problems such as wavelength- and polarization- dependence, and high insertion loss. As an alternative, optoelectronic mixing utilizing nonlinearity in three terminal devices such as HEMTs [3] and HBTs [4] has been demonstrated. These methods, however, require high frequency electrical LO signal sources at base stations. In order to avoid these limitations, an all-optical approach is quite attractive. When optical IF signals are up-converted to the optical LO signals via optical components, IF signals appear as far as IF frequency from the LO signals after PD detection. Fig. 1 shows a brief process.

In this paper, we present a new all-optical signal up-conversion scheme using the cross gain modulation in a semiconductor optical amplifier (SOA). Optical IF signals are mixed with an optical LO signal in the SOA and up-converted after detection in PD. This scheme does not have wavelength- or polarization-dependence, and signal up-conversion is possible for a wide range of separation between IF and LO wavelengths as long as both are within the SOA gain bandwidth. Moreover, the signal up-conversion is not limited by the SOA modulation bandwidth and the positive conversion efficiency can be achieved.

II. Experiment and Results

Fig. 1 shows the experimental setup for all-optical signal up-conversion with an SOA. The optical LO signals are generated from an MZM biased at V_π for DSB-SC modulation. The LO frequency of 25 GHz is used because of the limited modulation bandwidth of the MZM available, but the present scheme should be applicable for higher LO frequencies. The MZM output is amplified by EDFA and spectrally filtered out by an optical bandpass filter to eliminate EDFA-induced noise. The optical IF signal is produced by the direct modulation of a

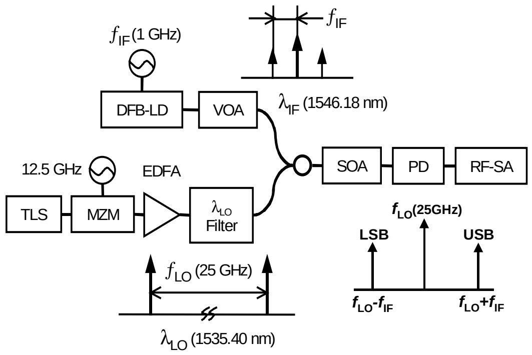

Fig. 1. Experimental setup for all-optical signal up-conversion using SOA. TLA: tunable light source, VOA: variable optical attenuator, RF-SA: RF-Spectrum analyzer.

DFB-LD at 1 GHz with 0 dBm power. It should be noted that the IF frequency can be varied without any performance degradation as long as it is within the SOA modulation bandwidth. The optical IF power is adjusted by an optical variable attenuator so that the peak power is maintained at –10.9 dBm at the SOA input port. Optical IF and LO signals co-propagate through the SOA and cross-modulate each other. Isolators are placed before and after the SOA to avoid any undesired optical feedback. No polarization control is required in this scheme.

Fig. 2 is an RF-spectrum of IF and LO signals before and after an SOA. In Fig. 2(b), one can observe clearly that the IF signal at 1 GHz is up-converted to LSB (24 GHz) and USB (26 GHz) after mixed with the optical LO signals separated by 25 GHz in the SOA. As can be seen in fig. 2(b), LSB and USB signals after the SOA have larger RF powers by about 10 dB compared to IF signal power before SOA (fig. 2(a)). This implies that the up-converted IF signal in SOA can have a gain because the SOA gain directly contribute to the up-conversion process. With this, the conversion efficiency can be much larger than schemes using external optical modulators [2]. It should be noted, however, the noise level increases due to SOA amplified spontaneous emission noise.

In addition, we confirm experimentally that the signal up-conversion is possible as long as both optical LO and IF signals are within the SOA gain bandwidth. This property should be very useful for radio-on-fiber transmission system applications in which one remote optical LO signals are provided for several WDM IF (or baseband data) signals at different wavelengths.

III. Conclusion

We presented a new all-optical signal up-conversion scheme using cross-gain modulation effect in SOA. Specifically, we showed experimentally that signal up-conversion is possible for the LO frequency that is much larger than SOA modulation frequency, and our scheme can provide positive conversion efficiency. In addition, signal up-conversion is possible for wide wavelength separation between LO and IF signals within the SOA gain bandwidth.

IV. Reference

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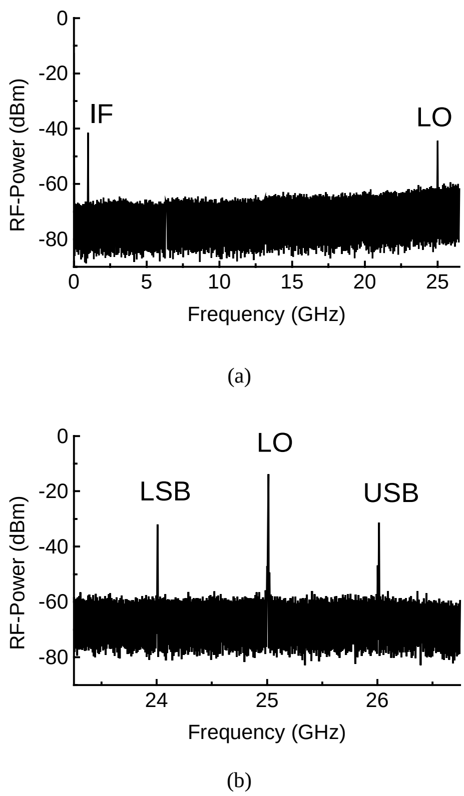

Fig. 2. RF-Spectra of IF and LO signals before (a) and after (b). SOA LSB and USB mean lower and upper sideband, respectively.