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RESEARCH ARTICLE

MICROWAVE PHOTONIC UP AND DOWN CONVERTER.

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Abstract

In this paper, both the up and down conversions of microwave photonic mixer are discussed and experimentally performed. The critical problem of a mixer i.e. mixing of spurious signals (spurs) is also suppressed by performing various techniques using different optical components.

Introduction:-

Microwave photonics is the combination of fiber optic and radio wave. Therefore, the advantages like high speed, large bandwidth, good isolation and immunity to electromagnetic interference come into account [1]. With good isolation, mixer is able to reduce the passage of LO towards the RF [2].

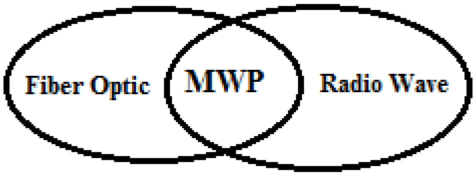


Fig. 1 Microwave photonics.

Microwave photonic mixer works as a down converter when desired frequency is less than the input frequency. It means the conversion of radio frequency (RF) into intermediate frequency (IF) takes place in such type of mixer. In the transmitter section of any system the mixer acts as an up-converter and this mixer converts IF to RF.

Zhenzhou Tang and Shilong Pan [3] presented microwave photonic mixer techniques to suppress the mixing spurs which are an inevitable problem. Huan Jiang et al. [4] generate optical single sideband through semiconductor optical amplifier (SOA) and gives higher sideband suppression ratio. Jianyu Zheng et al. [5] proposed and experimentally demonstrated an optical-assisted microwave mixing technique. Ganesh K. Gopalakrishnan [6] investigated microwave optical mixing in different configurations of $LiNbO_3$ Mach-Zehnder interferometric modulators. Charles Middleton et al. [7] discussed wideband photonic frequency converter based on optical sideband filtering. Yongsheng Gao et al. [9] demonstrated photonic microwave mixer based on an integrated dual parallel Mach-Zehnder modulator (DPMZM).

Microwave photonic down converter:-

Sinusoidal input is given to the two Mach-Zehnder modulators as shown in fig 2. RF signal is given to MZM1 and LO is fed to MZM2. An optical filter is used to filter the carrier signal which is produced by the light source and is given to both MZM1 and MZM2 through the coupler. RF signal is at 18GHz and LO signal is at 15.93GHz frequency. An optical hybrid is used to provide the output of two erbium doped fiber amplifiers (EDFA) to the cascaded photo-detectors (PD). The light source is at 1552.5nm and responsivity of PD is 0.65.

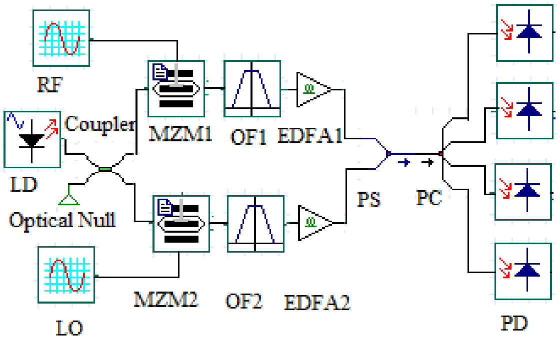


Fig. 2 MPM using two parallel MZM's

This system performs the basic function of the mixer i.e. conversion of RF to IF using LO as reference. The combination of power splitter and combiner is used as the optical hybrid in the structure.

Microwave photonic up converter:-

Fig. 3 shows the experimental demonstration of the frequency up-converter based on polarization rotation of SOA and optical filtering. A laser diode (1550.1nm) is used as light source for modulation in dual drive Mach-Zehnder modulator (DMZM). A sinusoidal LO signal of frequency 10GHz is given to the DMZM through 90° hybrid coupler.

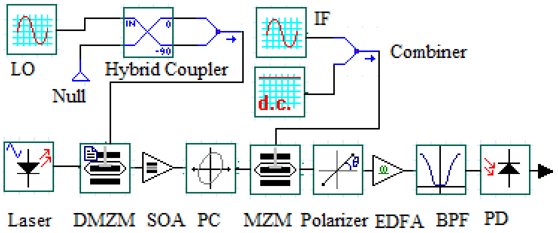


Fig. 3 MPM using semiconductor optical amplifier

The DMZM is followed by a semiconductor optical amplifier (SOA) which gives polarization rotation to the system and polarization controller controls the angle of the rotation. The specifications of the SOA are: current = 250mA, length = 0.03mm. IF signal is applied to the MZM that is connected in series with the polarizer. Both carrier and sideband signals are present at the output of the 45° polarizer as shown in fig. 6(a). An optical filter is placed after the amplifier which filter outs the carrier. Photo-detector converts the optical signal to the electrical signal. Fig. 6(b) shows the output of the photo-detector.

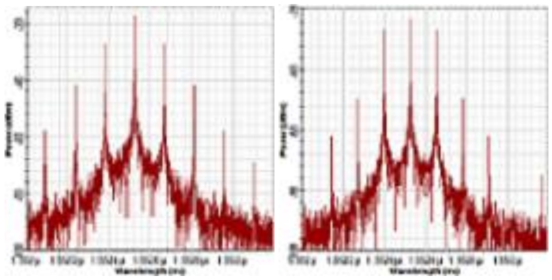
Experimental results and discussions:-

Down-converter:-

The output of MZM1 can be written as:

$$O/P_1 = B_{\pm1}e^{(f_c+f_r)t} + B_0e^{f_ct}$$

Where f_c and f_r are the frequencies of carrier signal and RF signal respectively. $B_{\pm}$, B_0 are the amplitudes of sidebands and carrier signal respectively.



(a) (b)

Fig. 4 Optical spectra of (a) MZM1 and (b) MZM2

The output of MZM2 can be written as:

$$\mathrm{O/P_2} = \mathrm{C_{\pm 1} e^{(f_c+f_l)t} + C_0 e^{f_c t}}$$

where $\mathrm{f_l}$ is local oscillator signal, $\mathrm{C_\pm}$ and $\mathrm{C_0}$ are the amplitudes of sidebands and carrier signal respectively. Fig. 4(a) and (b) shows the output of the two modulators.

The signals from both the MZM's enters to the optical filters which filter outs the carrier signal and positive order sidebands. Therefore, the output becomes:

$$\mathrm{O/P_1^* = B\_e^{(f_c-f_r)t}}$$
$$\mathrm{O/P_2^* = C\_e^{(f_c-f_l)t}}$$

The output of the optical hybrid is:

$$\mathrm{H_1 = B\_e^{(f_c-f_r)t} + C\_e^{(f_c-f_l)t}}$$
$$\mathrm{H_2 = B\_e^{(f_c-f_r)t} - C\_e^{(f_c-f_l)t}}$$
$$\mathrm{H_3 = B\_e^{(f_c-f_r)t} + jC\_e^{(f_c-f_l)t}}$$
$$\mathrm{H_4 = B\_e^{(f_c-f_r)t} - jC\_e^{(f_c-f_l)t}}$$

Now, these outputs from the optical hybrid act as inputs to the PD's. Therefore, Fig 5 shows the final outputs from the all PD's that are as follows:

$$\mathrm{PD_1 = (B\_\cos f_r t + C\_\cos f_l t)^2}$$
$$\mathrm{= (B_-^2 \cos f_r^2 t + 2B\_C\_\cos f_r t * \cos f_l t + C_-^2 \cos f_l^2 t)}$$
$$\mathrm{= \frac{1}{2} B_-^2 (1 + \cos 2f_r t) + B\_C\_\cos(f_r - f_l) + B\_C\_\cos(f_r - f_l) + \frac{1}{2} C_-^2 (1 + \cos 2f_l t)}$$
$$\mathrm{PD_1 = B\_C\_\cos(f_r - f_l)t}$$

Similarly'

$$\mathrm{PD_2 = -B\_C\_\cos(f_r - f_l)t}$$
$$\mathrm{PD_3 = -B\_C\_\sin(f_r - f_l)t}$$
$$PD_4 = B\_C\_sin(f_r - f_l)t$$

Up-converter:-

The fields of carrier and sideband are given as:

$$\begin{pmatrix} A_c(t) \\ A_b(t) \end{pmatrix} = \begin{bmatrix} A_c e^{j(f_c t+\gamma)} \\ A_b e^{j f_b t} \end{bmatrix}$$

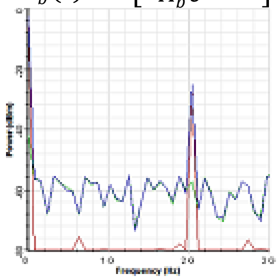
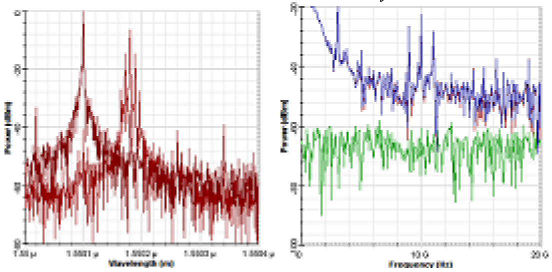


Fig. 5 Electrical spectra observed after PD

A_c and A_b are the amplitudes of carrier and sideband signals. Sideband frequency is denoted by f_b and γ is the phase difference.

These signals after passing through the SOA become:

$$\begin{pmatrix} A_c^*(t) \\ A_b^*(t) \end{pmatrix} = \begin{bmatrix} A_{cx}\, e^{j(f_c t+\gamma)} \\ A_{bx}\, e^{j f_b t} + A_{by}\, e^{j f_b t} \end{bmatrix}$$



(a) (b)

Fig. 6:- (a) Optical spectra measured after the polarizer and (b) electrical spectra of the photo detector

MZM's output is given as:

$$\begin{pmatrix} A_c^{**}(t) \\ A_b^{**}(t) \end{pmatrix} = \begin{bmatrix} A_{cx}\, e^{j(f_c t+\gamma)} \\ A_{bx}\, e^{j f_b t} + A_{by}\,(t) e^{j(f_b t+\Delta(t))} \end{bmatrix}$$

$\Delta(t)$ is the polarization angle of polarizer. Therefore, polarizer gives the output:

$A_\Delta(t) = A_{c\Delta} e^{j(f_c t+\gamma)} + A_{x\Delta} e^{j f_b t} + A_{y\Delta}(t) e^{j(f_b t+\Delta(t))}$

Conclusion:-

The up and down conversions are experimentally performed and results are shown via opti-system. Polarization rotation process of the SOA and polarizer's are observed. Also, the recent technique used to suppress the mixing spurs is studied.

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