The First Experimental Results of mm-Wave Generation by Photomixing

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***Abstract*—Generating mm-wave signals by optical techniques is very attractive solution to obtain high purity mm-wave signals. In order to generate mm-wave signals, photomixing experiments are made by some optical components with 1550 nm wavelength and two discrete laser sources generating 1550 nm CW (Continuous Wave) optical signal. This is our first experimental results of mm-wave generation by the phootomixing. We have expected that the photomixing technique by two discrete laser sources can be helpful to characterize a wideband opto-electric component.**

I. Introduction And Background

PHOTOMIXING is a well-known technique to make mm-wave signals. An extremely wide bandwidth afforded by the characteristics of optical components and simple configuration compared to electronic based techniques are advantages of the mm-wave generation through the photomixing. It can be used in various applications, such as broadband fiber-radio wireless transmission, high-speed measurement, mm-wave sensing and imaging, and local signal supply for radio telescopes [1]. In addition to the advantage of the photomixing technique using 1550 nm wavelength, it is easy to implement the experiments because the abundant optical components developed for optical communication systems compared to 800 nm wavelength bands. However, the photomixing based on photonic technologies has some disadvantages, including a limitation of its size and high cost compared to electronic systems because it depends on the size and cost of the optical components.

In this paper, we have made the photomixing experiment using two discrete laser sources and 45 GHz photodiode (PD). A polarization dependent loss have measured. As the results, it is can be used for characterization of high-speed optoelectric components.

II. Experimental Results

The photomixing experiment set-up using 1550 nm two discrete laser sources and some optical components is shown in Fig. 1. Continuous wave (CW) optical signals with difference wavelengths are excited from the first and second tunable laser source (hereafter called the "TLS 1" and "TLS 2"). Optical outputs power and wavelength of the TLS 1 and TLS 2 are λ_1 and P_1, λ_2 and P_2, respectively. The optical signals were combined with a 3-dB coupler which is optically mixed two CW optical signals. One of the branches in the 3-dB coupler is connected to an optical spectrum analyzer for monitoring the optical signals excited by TLS 1 and TLS 2. The other branch of the 3-dB coupler is connected to a 9:1 coupler which has two branches including 0.5 dB insertion loss (IL) and 10 dB insertion loss (hereafter called the "10 % branch"). The optical signals through 0.5 dB insertion loss branch (hereafter referred to as the "90 % branch") is inserted to 45 GHz photodiode to make mm-wave signals. The mm-wave signals converted from optical signal to electrical signals by a photodiode (PD) are measured by electrical spectrum analyzer.

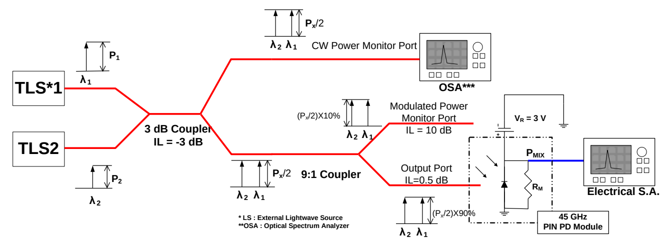

Fig. 1. Photomixing experiments set-up.

The photomixed optical signals of the 90% branch in the 9:1 coupler can be calculated as follows [2], [3].

$$P_{MIX,OPT} = \frac{0.9P_1}{2} + \frac{0.9P_2}{2} + 2\sqrt{\frac{0.9P_1}{2}\cdot\frac{0.9P_2}{2}}\cos(\phi_P)\cos(2\pi f_{MIX} t) \quad (1)$$

where, $P_{MIX,OPT}$, P_1, P_2, Φ_P, and f_{MIX} are the photomixed optical signal of the 90 % branch in the 9:1 coupler, CW output power of TLS 1, CW output power of TLS 2, the angle of polarization differences between TLS 1 and TLS 2, and the frequency of the photomixed output. The frequency of the photomixed output is decided by the wavelength differences between TLS 1 and TLS 2.

Output currents of the PD can be estimated as follows,

$$\begin{aligned} i_{PD} &= R_{dc}\left[\frac{0.9P_1}{2} + \frac{0.9P_2}{2} + \rho_{PD}\cdot 2\sqrt{\frac{0.9P_1}{2}\cdot\frac{0.9P_2}{2}}\cos(\phi_P)\cos(2\pi f_{MIX} t)\right] \\ &= R_{dc}\cdot\left[\frac{0.9P_1}{2} + \frac{0.9P_2}{2}\right] + R_{dc}\cdot\rho_{PD}\cdot 2\sqrt{\frac{0.9P_1}{2}\cdot\frac{0.9P_2}{2}}\cos(\phi_P)\cos(2\pi f_{MIX} t) \\ &= R_{dc}\cdot\left[\frac{0.9P_1}{2} + \frac{0.9P_2}{2}\right] + R_{RF}\cdot 2\sqrt{\frac{0.9P_1}{2}\cdot\frac{0.9P_2}{2}}\cos(\phi_P)\cos(2\pi f_{MIX} t) \\ &= i_{PD,dc} + i_{PD,RF} \end{aligned} \quad (2)$$

where, i_{PD}, $i_{PD,dc}$, $i_{PD,RF}$, R_{dc}, R_{RF}, Φ_P, and ρ_{PD} are the PD output current of the photomixed optical signal, the dc term of the PD output current, the RF term of the PD output current, DC responsivity and RF responsivity of the PD, the polarization angle difference between two discrete TLS. and the (dimensionless) photodetector frequency response. Note that $\rho_{PD} \rightarrow 1$ as $f_{MIX} \rightarrow 0$, therefore, $0 < \rho_{PD} \leq 1$ [4].

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For the experiment set-up discussed here, the RF power converted from the photomixed optical signal to mm-wave signal by the PD measures

$$P_{MIX} = \left[i_{PD,RF}\right]_{rms}^{2} \cdot Z_M \qquad (3)$$

where

$$\left[i_{PD,RF}\right]_{rms} = R_{RF} \cdot \sqrt{2 \cdot \frac{0.9P_1}{2} \cdot \frac{0.9P_2}{2}} \cos(\phi_P) \qquad (4)$$

is the root-mean-square (rms) RF photocurrent and Z_M is the magnitude of the termination impedance of the electrical spectrum analyzer. Generally, Z_M is approximately 50 Ω.

Calculation results of polarization dependency in the photomixing experiment set-up discussed here is shown Fig. 2. There is assumed that the P1 and P2 is fixed as 0 dBm, the polarization angle differences (Φ_P) are varied from 0^o to 90^o. We calculated the photomixed output power. We can found that the photomixed output power is decreased by increasing the polarization angle difference. There is dramatically reduced around 80^o of the polarization angle difference. This is because electric fields of two optical signal is canceled when the polarization angle difference is reached to 90^o. Accordingly, the polarization angles should be seriously controlled in the photomixing experiment.

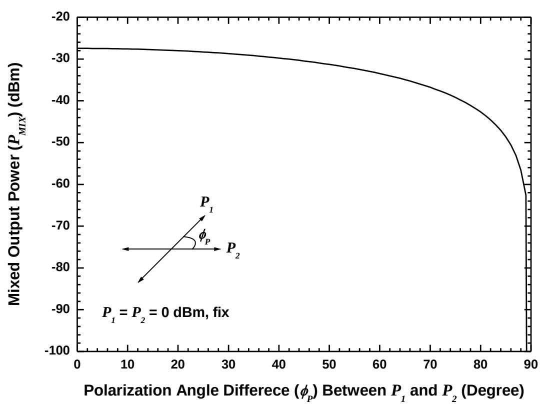
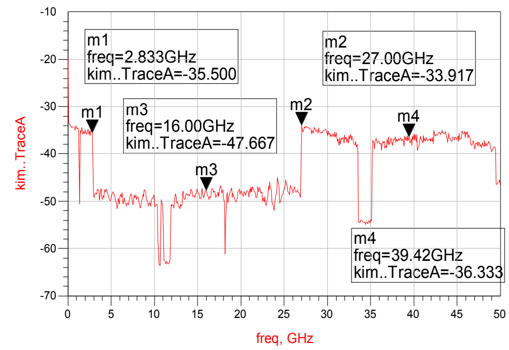
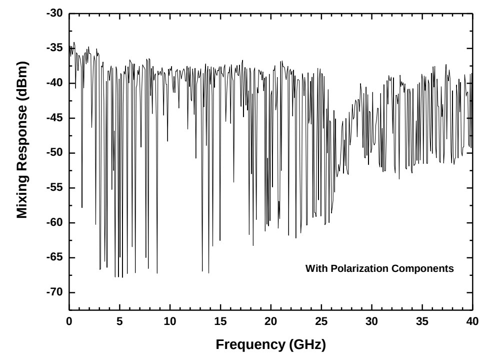


Fig. 2. Calculation results of polarization dependency in the photomixing experiment set-up discussed here.

In order to verify the photomixing performances, optoelectric (OE) conversion responses with frequency were measured with and polarization control components. The polarization dependency of the photomixing is shown in Fig. 3. Fig. 3 (a) and (b) are without polarization control components and without polarization components. As we mentioned above, there are appeared many fluctuation in Fig. 3(a) because of the polarization angle difference between two discrete optical sources, TLS 1 and TLS 2. However, with polarization control components, there can be observed more stable performance in Fig. 3 (a) than that of Fig. 3(b). Consequently, the mm-wave generated by photomixing with two discrete laser sources can be used for characterization of high-speed OE components.



(a)



(b)

Fig. 3. Photomixing performances (a) without polarization control and (b) with polarization control.

III. Conclusion

We are made mm-wave signals through photomixing technologies of two discrete 1550 nm optical sources. The polarization problem is occurred between two discrete optical sources. Therefore, the polarization control is a key issue to make the photomixing system. it is can be used for characterization of high-speed optoelectric components.

Acknowledgement

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