Photodetection, Photonic Feeding Coplanar Patch Antenna and Transmitting Experiment for Radio-on-Fiber System

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Abstract — **In this paper, we presented an experiment on optical modulation, photodetection, photonic feeding and RF transmitting radiation system. The experiment showed a RF power of more than 10dBm at both 10GHz and 20GHz from a photodetector (PD). A coplanar patch antenna has been used as radiating antenna, which has a CPW fed line and then easy to connect with the PD and has been designed based on a concept of coplanar patch. The transmitting experiment demonstrated the effectiveness of the direct photonic feeding antenna and its potential application to the real radio-on-fiber system.**

I. Introduction

In a base station of radio-on-fiber system, there are two key devices: a high performance photodetector (PD), which can efficiently operate at high frequencies and generate sufficient RF power from optical signals, and an antenna, which can easily be integrated with the PD and radiate the power efficiently [1]-[4].

In our previous paper, we proposed a concept that uses an optical amplifier (EDFA) for optical input before the PD instead of using RF amplifier after the PD [5]-[6]. The advantage of using optical amplifier is not only its huge bandwidth compared with the RF device, but also the larger equivalent gain for the system. The RF output power from a PD is proportional to not only the gain, but the square of the gain of the used optical amplifier. This can be easily understood since the photodetection follows square law, provided the PD is not saturated. Our fundamental experiment successfully confirmed this concept where relatively large power (for example, about 10dBm @10GHz and 38GHz) have been obtained in the experiment. To efficiently radiate the generated RF power and make an easy integration with the PD, we proposed a new antenna called coplanar patch antenna (CPA) [7]. In this paper, we first show the measured results on the optical modulation and photodetection, and then demonstrate the performance of a two-element CPA, which is designed and fabricated for directly connection to the PD, and present the experimental results on the photonic feeding to the antenna and the radiation and transmitting experiment.

II. Experimental Setup

Figure 1 shows an experimental setup for optical modulation using an optical modulator, detection using a photodiode, and radiation and transmission using a CPA and a standard horn antenna. The light source is a laser diode (LD) at 1.55 μm. The optical modulator is a $LiNbO_3$ travelling-wave optical modulator with 3dB bandwidth of 40GHz, and can also operate extent to 60GHz but with much lower response. The photodiode used in the photodetection is an wide band device called uni-traveling-carrier photodiode (UTC-PD) [8]. This photodiode can not only operating over 100GHz but also can handle a relatively large input optical power. The optical wave is modulated by the microwave or millimeter-wave (MMW) sub-carrier, which fed from an RF generator and amplified up to about 20 dBm, through the optical modulator and then amplified by an optical amplifier (EDFA) with an output up to 20dBm. Bias voltage applied to PD is kept at -2.5V. The RF output from the PD and power received at the standard horn are measured on a spectrum analyzer. The distance between the radiating CPA to the receiving horn is fixed at 75cm in this experiment.

III. Modulation and Photodetection Results

Figure 2 shows the optical spectra of modulated optical waves at 10GHz and 20GHz. The modulation indices for each sub-carrier are adjusted by changing the bias voltage applied to the modulator. The photodetection output directly depends on the modulation index, and in our experiment, modulation sidelobes about 3dB lower the central carrier peak give a maximum output. This is consistent with the theoretical analysis for a Mach-Zehnder interferometer type modulator. The RF outputs at 10 and 20GHz versus input optical power into the PD are shown in Fig. 3. These results show a relatively large power of more than

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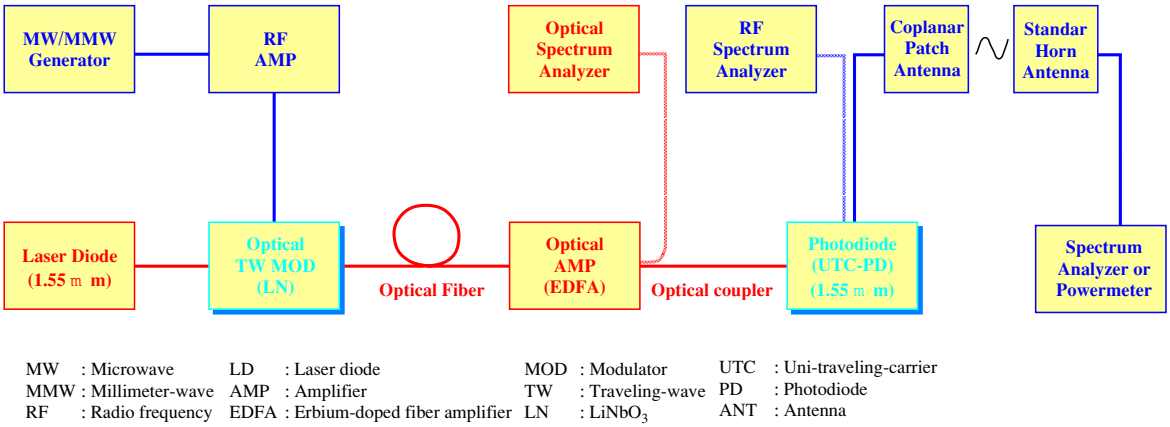

Fig. 1 Experimental setup of optical modulation using an optical modulator, detection using a photodiode, radiation using coplanar patch antenna and receiving using a standard horn antenna.

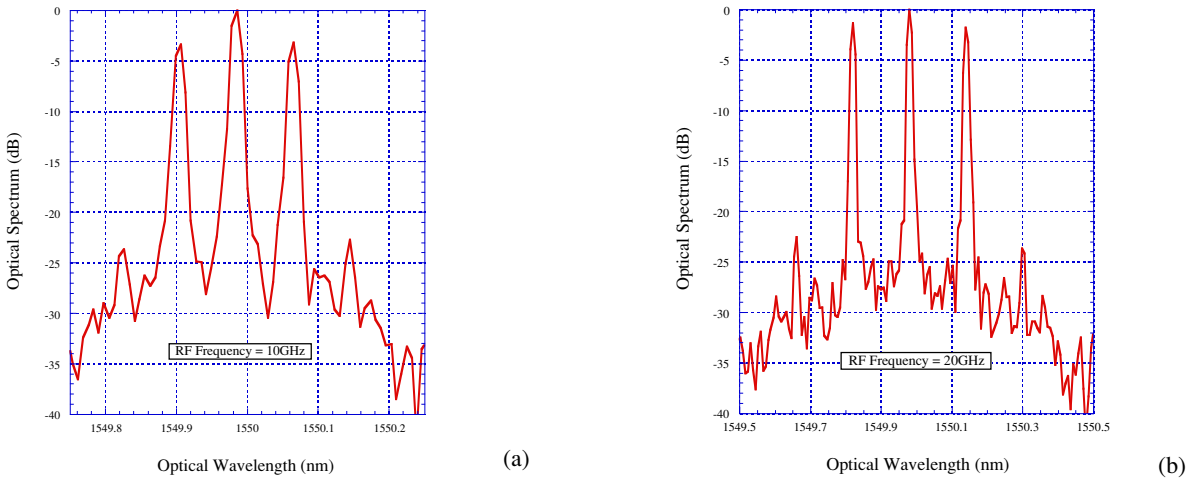

Fig. 2 Optical spectra of optical wave modulated at (a) 10 GHz and (b) 20 GHz.

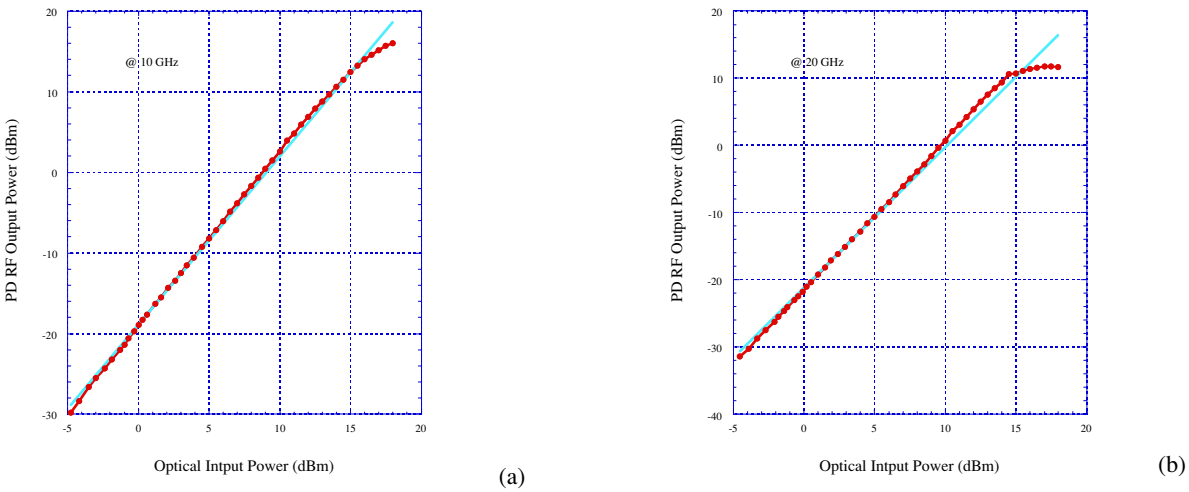

Fig. 3 RF output from photodetector at (a) 10 GHz and (b) 20 GHz.

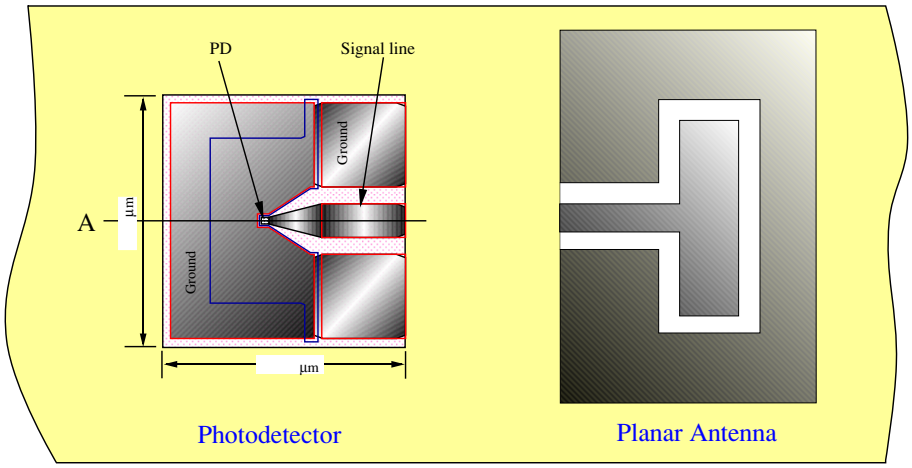

Fig. 4 Photodetector structure and planar antenna to be integrated with the PD.

10dBm at both 10GHz and 20GHz from the PD, which are close to or even larger than the required power for direct feeding a typical indoor millimeter-wave radiation system. This provides a possibility to construct a simple radio-on-fiber system without using a microwave or millimeter-wave amplifier.

IV. Coplanar Patch Antenna and Transmitting Experiment

A. Coplanar Patch Antenna

With the large RF output power obtained from the experiment, we now consider a direct integration with antenna in order to construct a simple RF system. Figure 4 shows a configuration of PD and a planar antenna. We have developed a new antenna called coplanar patch antenna (CPA), which has a coplanar waveguide fed line to connect to the PD and a coplanar patch for radiation, as shown in Fig. 5 [7]. The simulation and experimental results showed advantages of the CPA such as easy connection to PD, high radiation efficiency, and unidirectional radiation pattern. To improve the gain of the CPA, we designed and fabricated a two-element CPA based on the concept of the coplanar patch, as shown in Fig. 6. Figure 7 and 8 show the return loss and the radiation pattern of the array antenna at X-band. The measured gain is about 11.5dB at 10GHz. We used this array antenna in the photonic feeding and transmitting experiment shown in Fig. 1. The coplanar patch array antenna was directly connected to the packaged PD.

A. Photonic Feeding and Transmitting Experiment

Following the experimental configuration shown in Fig.

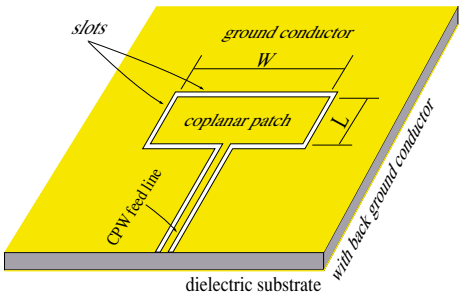

Fig. 5 Configuration of CPW-fed coplanar patch antenna.

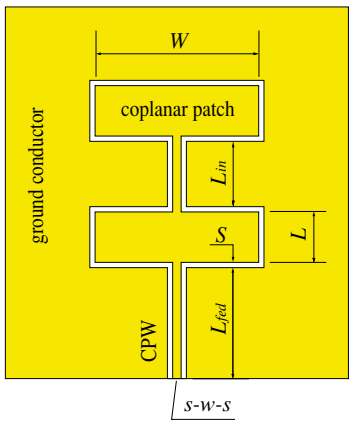

Fig. 6 Two-element coplanar patch array antenna

1, we directly fed the coplanar patch array antenna using the photodetector without any RF amplifier between the antenna and PD. The RF power was then generated by the PD from input optical signals and radiated by the coplanar patch array antenna. The radiated power is received by a standard horn antenna, which has a gain of 11.2 dB at 10GHz and is located at distance 75cm from the patch array. The received power is shown in Fig. 9. At 10dBm optical input, for example, the received power is about -22dBm, which is a large enough value for a conventional wireless system. This result confirms our consideration again that we can use the optical power to overcome the weakness of the microwave and millimeter-wave and construct a simple photonic feeding and RF radiation system.

V. Conclusion

In this paper, we have presented an experiment on optical modulation and photodetection at microwave frequencies. The experimental results showed that we can obtain a relatively large power of more than 10dBm at both 10GHz and 20GHz from the photodetector and we can then construct a simple photonic feeding RF radiation system. A CPA has been used as radiating antenna, which has a CPW fed line matching to the PD and has been designed based on a concept of coplanar patch introduced in [7]. The transmitting experiment demonstrated the effectiveness and usefulness of the direct photonic feeding antenna and its potential application to the real radio-on-fiber system. This simple configuration would provide a good solution and become a key technology for the future photonic and microwave/millimeter-wave wireless communication systems.

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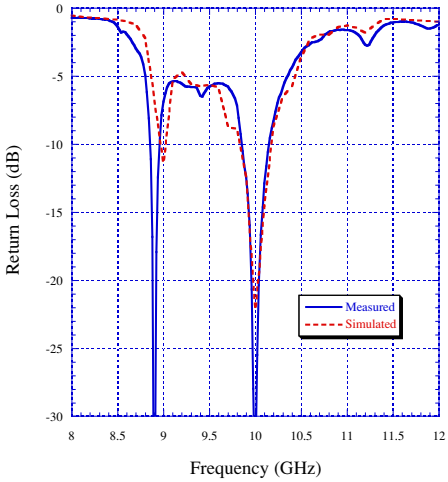

Fig. 7 Measured and simulation results of return loss of the coplanar patch antenna.

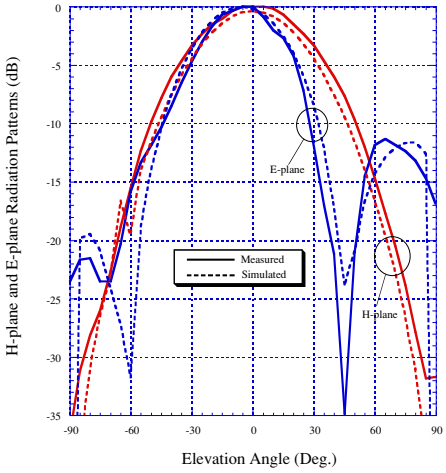

Fig. 8 Simulated and measured radiation pattern in E-plane and H-plane at 10GHz.

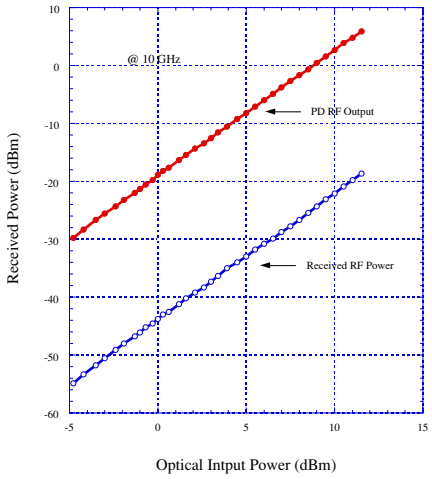

Fig. 9 Power generated by PD and power radiated by coplanar patch array antenna and received by horn antenna.