A 650 GHz Photonic transmitter Design Using CPW-fed Slot Antenna

Yi-Chun Yu*[1], Shih-Yuan Chen[1], An-Shyi Liu[1], Ruey-Beei Wu[1] and
Chi-Kuang Sun[2]

[1]Graduate Institute of Communication Engineering, National Taiwan
University, Taipei, Taiwan, 10617, ROC
Email:ruwu@ew.ee.ntu.edu.tw
[2]Graduate Institute of Electro-Optical Engineering, National Taiwan
University, Taipei, Taiwan, 10617, ROC

Abstract—**In this paper, one planar slot antenna with GaAs substrate for a 650GHz edge-coupled photonic transmitter application is demonstrated. In our design, the photonic transmitter consists of the CPW-fed slot antenna, bandpstop filter and DC pad. The millimeter wave components are cascaded with a metal-semiconductor-metal traveling-wave photodetectors (MSM-TWPD) [1]. This design has been fabricated on GaAs substrate and the radiation power is measured by liquid-helium-cooled bolometer. The measurement result shows the feasibility of a compact THz photonic transmitter design excited by a low power laser with a high conversion efficiency.**

I. INTRODUCTION

Terahertz technology has drawn more and more attention in recent years. However, the difficulty of generation of THz electromagnetic wave efficiently is a main problem. In general, purely electronic oscillators degrade their performance as the frequency exceeds 100GHz. On the optical side, quantum cascade lasers also show notably roll-off of their emission characteristics below the frequency of 10Thz. Therefore, the emission power exhibits a spectral "black hole" (100GHz~10Thz) in the far infrared spectrum.

Some vertical-illuminated Photonic transmitters have demonstrated the generation of narrow-band THz waves range from 100GHz to 1THz. The output power of 10mW at 100GHz and 120 μ W at 300GHz had been investigated in literatures [2]-[3]. However, the performance of photonic transmitter at higher frequency is not satisfactory. The vertical-illuminated structure and the photonic transmitter with poor light-THz conversion efficiency also make it difficult to be integrated with a low power laser.

In order to improve the drawbacks shown in the above paragraph, an edge-coupled membrane photonic transmitter with high efficiency is proposed in this paper. The measurement shows the maximum conversion efficiency at 645GHz is about 0.11%, corresponding to a maximum average power of 3.9 μ W, and a maximum peak power of 13.2mW under excitation by quasi-CW optical pulse sources.

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II. DESIGN of ANTENNA

The topology of photonic transmitter in this study is shown in Fig. 1. The photonic transmitter is composed of a planar slot antenna, a bandpstop filter, a DC pad, and a metal-semiconductor-metal traveling-wave photodetector (MSM-TPD)[1]. A bias current is fed by a DC probe and the current is conducted by a CPW line. As a result, a DC current is fed through the slot antenna.

To approximately match the impedance of MSM-TWPD, the total length of slot antenna is designed roughly to be one guided wavelength. The RF signal is converted from the MSM-TWPD. In order to radiate the RF signal fully by the slot antenna, one bandstop filter is cascaded with the slot antenna to avoid the RF power loss, which leaks to the DC probe pad and decreases the radiation efficiency.

The bandpass filter is implemented meander line as shown in Fig. 1. It acts as a high impedance transmission line at the frequency band of the designed slot antenna. And the performance of the meander is the same as a bandstop filter.

The dimensions of the slot antenna are 200 μm and 45 μm in length and width respectively. The width of input CPW line is 6 μm and the slot width is 8 μm. The width and length of dc probe pad are both 100 μm. The length of each section in the meander line is 10 μm, and the width is 2 μm.

The vertical dimensions of our structure are illustrated in Fig.2, which is with gold as the metal layer and the GaAs substrate. And the AlGaAs (ε_r=13.18) layer below the GaAs substrate acts as a cladding layer. The decreasing ratio of Al to Ga in AlGaAs layer and the increasing thickness of it are tuned for optimum wave-guiding. In some recent research, a silicon lens is often included to confine the radiation power [4]. But in our edge-coupled design, a large silicon lens will make it difficult to focus laser power on our transmitter. To solve this problem, we forsake the large silicon lens, and fabricate our membraneous structure on glass. The glass layer is 150 μm in thickness.

III. SIMULATION and MEASUREMENT

The return loss of the designed slot antenna is simulated by full-wave solver AnSoft Ensemble 6.0 as shown in Fig. 3. As indicated in this figure, the 10dB bandwidth is 22.5% and the center frequency is 680GHz. The conventional vector network analysor can not measure such a high frequency band. Therefore, the radiation power is reflected by a paraboloidal mirror, and measured by the Bolometer. The photocurrent measured by the Bolometer is then calculated to the power conversion. The normalized power response versus frequency is shown in Fig.4. In the measurement, the maximum power conversion is at 645GHz. The frequency shift is caused by the large probe pad. Fig. 5 illustrates the conversion efficiency versus input power in different bias voltage. As shown in this figure, the conversion efficiency is directly related with bias voltage. In addition, the photonic transmitter comes to saturation with high input power, and the input power of maximum conversion efficiency is increasing with bias voltage. The best conversion efficiency 0.11% occurs at the input power of 3.35 mW as the bias voltage is 15 volts.

IV. CONCLUSIONS

In summary, an edge-coupled membrane terahertz photonic transmitter with dc bias applied on trace line is fabricated. The high conversion efficiency (0.11% corresponding to 3.9 μW at 645GHz, while bias voltage is 15V, input power is 3.35mW) is about 20 times higher than the optimum value that has been reported in literature [5] at a similar radiation frequency. By the means of the increasing of bias voltage, the better performance is expected.

V. REFERENCES

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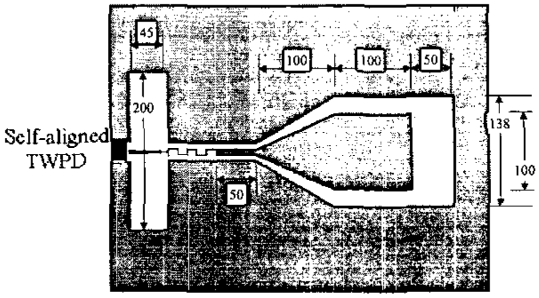

Fig. 1. The topology of our photomic transmitter. (unit in μm)

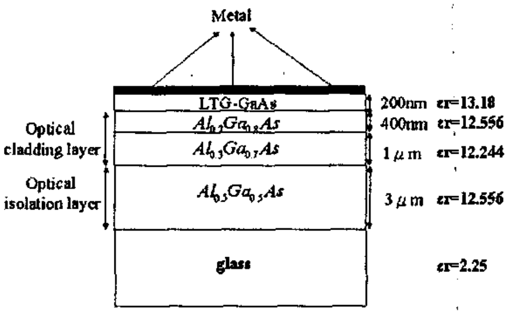

Fig. 2. The layer structure of our process.

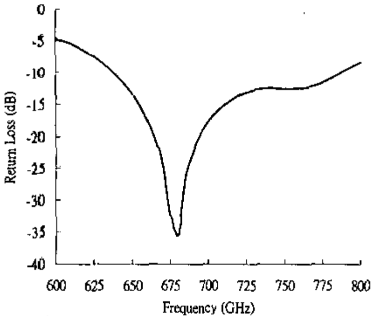

Fig. 3. The simulation of return loss.

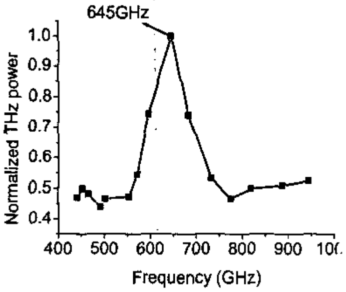

Fig. 4. The measurement of normalize. power ratio response.

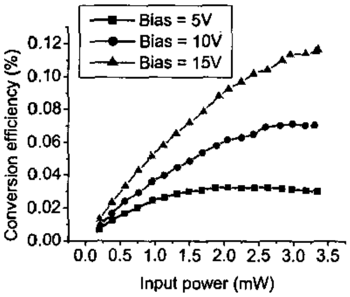

Fig. 5. The measurement of conversion efficiency versus input power with different bias