High-power and Broadband Sub-terahertz Wave Generation Using a J-band Photomixer Module with Rectangular-waveguide Output Port

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***Abstract*—A high-output-power photomixer module operating at 200 - 500 GHz has been developed. The module consists of a uni-traveling-carrier photodiode, a PD-waveguide mode-conversion coupler, and a compact metal package with a rectangular-waveguide that outputs sub-terahertz wave. The fabricated module exhibits a 10- dB down bandwidth of about 300 GHz and an output power as high as -2.7dBm at 350 GHz. This is the highest value ever reported for a photomixer module operating at 350-GHz band.**

I. INTRODUCTION

Recently, terahertz and sub-terahertz waves (hereafter called terahertz-waves) have been actively investigated for various applications, such as the high-capacity wireless communication, the local signal supply for radio telescope, and remote imaging and sensing. Compared with micro- and millimeter-waves, terahertz-waves offer high-capacity information delivery due to their higher frequency and high spatial resolution due to their shorter wavelength. Compared with IR and visible light, the beam scattering by dust, smoke, and fog is small due to their longer wavelength. Moreover, the difference between the background radiation energies of black body for the high and low temperatures such as fire and humanbody is much smaller in the wavelength range of terahertz-waves than those in IR and visible light range. The small beam scattering and the relatively small background noise would be especially advantageous for remote spectroscopic sensing in disaster areas. They will make it possible to detect the presence of poisonous and inflammable gasses through dust, smoke, and fire.

A key device for realizing these systems is a compact, high-power, and broadband terahertz-wave generator. Thus, a photomixer module operating at 200 - 500 GHz has been developed based on the high-power millimeter- and sub-millimeter-wave generator technology developed for W-, F- [1], D-, and J-bands [2].

II. DESIGN AND FABRICATION

Figure 1 shows the band diagram of the photodiode (PD) used in the photomixer module. It is a kind of the uni-traveling-carrier photodiode (UTC-PD). The UTC-PD has a merit of both high-speed and high-output power operation owing to its unique carrier transport mechanism [3]. The structure shown in Fig. 1 was designed to have a higher responsivity than that of the UTC-PD with the same neutral absorption layer thickness. Although the maximum output power might be slightly lower, we selected this structure in order to obtain high output power with relatively-low required optical input for practical use.

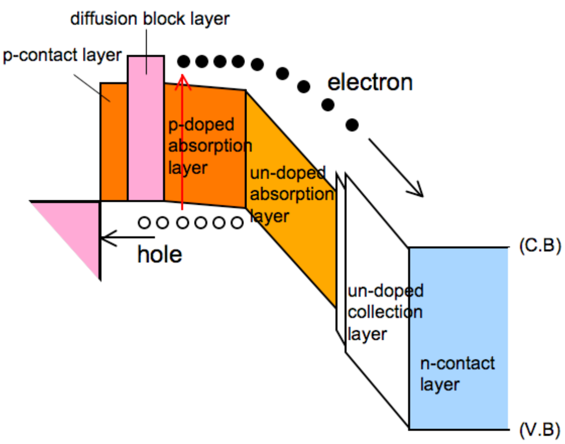

Fig. 1 Band diagram of the photodiode

A short-stub is integrated with the PD chip to increase the output power at around the designed center frequency of 350 GHz. The pulse response of the PD chip was measured by EO-sampling to evaluate the effect of the short-stub. Figure 2 shows the frequency dependence of the relative response of a PD chip with the short-stub converted from the measured waveform of the pulse photoresponse. As shown in Fig. 2, the fabricated PD chip exhibits a resonant peak at around 300 GHz. This resonant frequency was about the same as the designed center frequency.

The photomixer module has a PD-waveguide mode-conversion coupler and an output rectangular-waveguide (WR-3). The coupler is fabricated on a quartz substrate and acts as a circuit to match impedance between the PD chip and the waveguide. For the operation at frequencies beyond the fundamental mode frequency range of WR-3 (up to 347 GHz), the coupler is designed by electro-magnetic wave simulator to properly suppress the propagation of higher-order modes. Figure 3 shows the simulated frequency dependence of S21 from the input port of the coupler to the output port of the waveguide. As shown in Fig. 3, higher-order modes are well suppressed below -30 dB up to 530 GHz.

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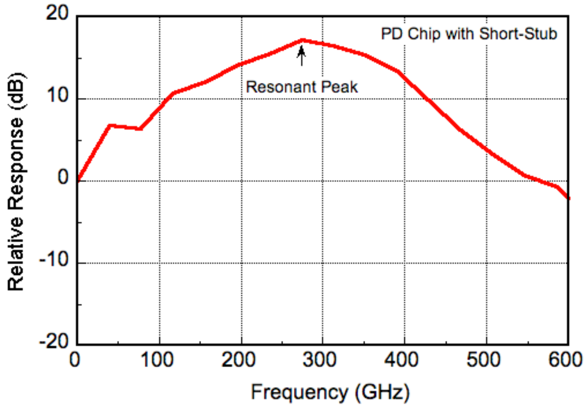

Fig. 2 Frequency dependence of relative response converted from measured pulse waveform

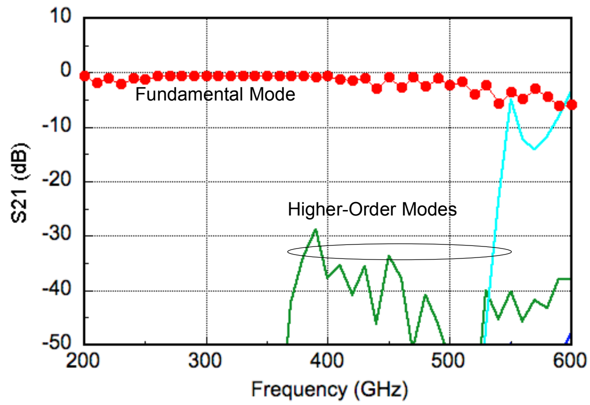

Fig. 3 Simulated frequency dependence of S21 for possible modes propagating the WR-3 waveguide

Figure 4 shows a photograph of the fabricated module. An optical fiber and a DC-bias cable are connected to the module to input RF-modulated light and supply DC-bias voltage, respectively. A standard WR-3 waveguide is connected to the rectangular-waveguide output of the module.

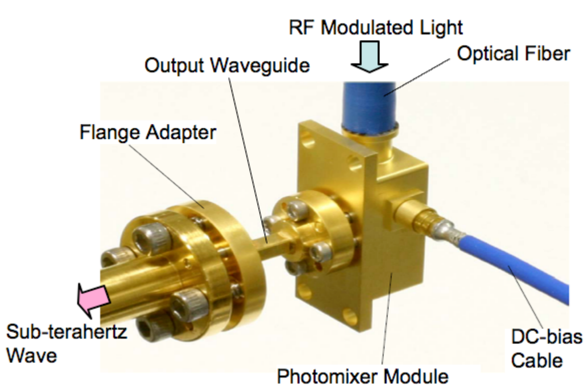

Fig. 4 Photograph of fabricated photomixer module

III. Results

The responsivity of the fabricated module was about 0.22 A/W, and the dark current was 20 nA at DC-bias of -1 V. At 350 GHz, the output power started to saturate above the photocurrent of 20 mA and DC-bias of -2.5 V.

The frequency dependence of the output power was evaluated by using RF-modulated light signal (beat signal) generated by combining two lights with different wavelengths at around 1.55 μm. The wavelength-tunable light source was a SANTEC TLS-210S. The RF output power was measured with a thermo-coupled power meter (Erickson PM-2). Figure 5 shows the frequency dependence of the output power generated from the module. The maximum output power was -2.7dBm at around 350 GHz for a photocurrent of 20 mA. This is the highest output power directly generated from a photomixer operating at 350 GHz band. The 10-dB down bandwidth was as wide as about 300 GHz, demonstrating that the rectangular-waveguide output scheme is applicable for broadband sub-terahertz-wave generation at frequencies beyond the fundamental mode frequency range.

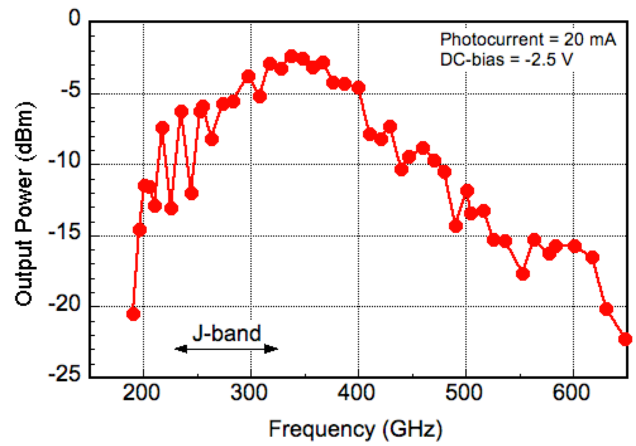

Fig. 5 Frequency dependence of output power

IV. Summary

A high-power and broadband photomixer module is fabricated and evaluated. The module exhibits a 10-dB down bandwidth of about 300 GHz and the maximum output power as high as -2.7dBm at 350 GHz.

Acknowledgement

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