Antenna Coupled THz Radiation Detectors

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***Abstract*— Receiving properties of slot antenna coupled warm carrier device were discussed. Since the sensitivity of the detector strongly depends on the antenna gain, it is important to improve the power gain of the antenna. In the case of the slot antenna, the power gain of 13 dBi was obtain at 700GHz by fabricating the two-dimensional 8 × 3 slot antenna arrays fed by CPW. The gain increased up to 31.5 dBi by coupling the double slot antenna with the extended hemispherical lens.**

***Index Terms*—Detector, microfabrication, slot antenna, terahertz**

I. Introduction

RECENTLY, the terahertz (THz) frequency region has attracted considerable attention as the remaining frequency resource for applications such as communications, imaging, medical diagnostics, health monitoring, agriculture, etc, and many researchers have been developing electronic devices for realizing these applications. An antenna coupled detector is one of the notable candidates for electronic devices used in the THz region. The useful properties of this device arise from nonlinear current-voltage (*I–V*) characteristics which persist up to the infrared region and the ability of a receiving antenna which converts infrared radiation to an infrared frequency voltage across the device. However, the fabrication of highly sensitive antenna coupled devices depends on the improvement of nanotechnology.

In the present paper, the receiving properties of the antenna coupled terahertz detectors, especially slot antenna coupled warm carrier devices will be discussed including the research for improving the device sensitivity.

II. Detection Properties of The Devices

A. Configuration of the device

We fabricated the single slot antenna coupled thin film warm carrier devices which have contact areas less than 8×10^{-10} cm^2. Figure 1 shows the SEM photographs of the fabricated device. Figure 1(a) is the general view of the device. The warm carrier detector is placed at the center of the slot. Figures 1 (b) and (c) are the magnified views of the center area of the antenna. Two arms are expanded from the antenna ground plane, and end of one arm is in contact with the circumferential area of the 7μm-radius-semicircular Ge film. The end of the other arm is in contact with the edge of Ge film at the center of the diameter of the semicircle. Figure 1(d) is the magnified photograph of the point contact area. We can see that the 0.2 μm-wide thin film gold line is in contact with the edge of the 0.4 μm-thick Ge film. The area at the point contact is around 8×10^{-10} cm^2. The resistance of the fabricated device was 1-2 kΩ.

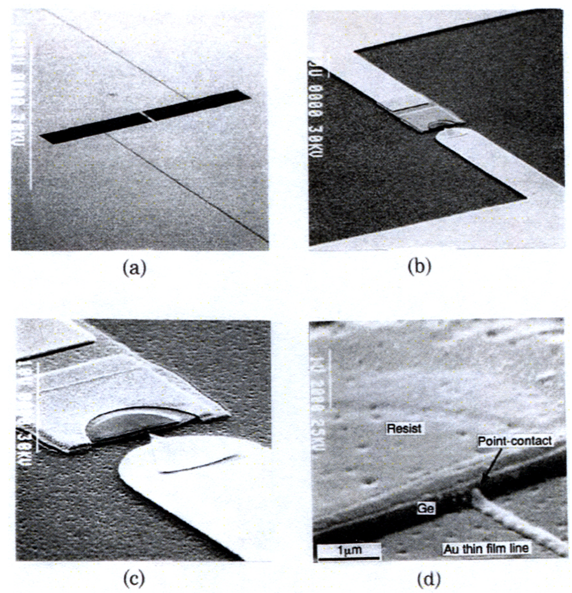

Fig. 1. SEM Photographs of the fabricated device.

B. Detection and mixing properties at 700GHz

Figure 2 shows the incident angle dependence of the detected voltage when the 700 GHz wave was irradiated on the device. It is found that the thin film antenna works as expected from the theory.

Figure 3 shows the bet note when 94 GHz signal and 47.1515GHz LO wave were irradiated on the device simultaneously. The beat note (IF output) was observed at 0.303GHz. The IF output is linearly proportional to the LO power and to the 94GHz signal.

The noise equivalent incident power density (NEI) of the device was 3.8×10^{-5} W/cm^2 for 700GHz. irradiation. This value is still high. This would be due to the small effective aperture of the antenna, because the effective aperture is

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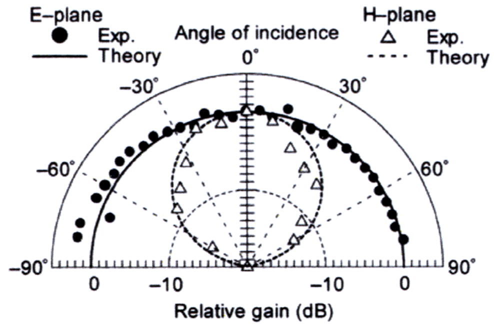
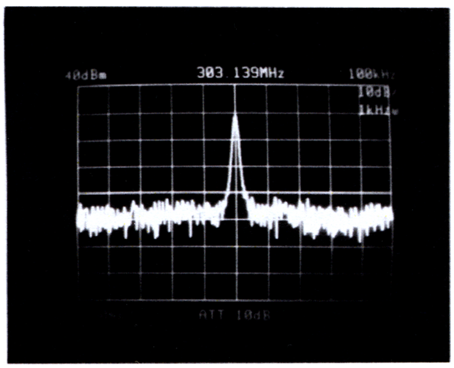


Fig. 2. Incident angle dependence of detected voltage, when the 700GHz wave irradiated on the single slot antenna.



$f_1 - n \times f_2 = 94 - 2 \times 47.1515 = 0.303$(GHz)

Fig. 3. Beat note when 47.1515GHz LO wave and 94GHz signal were irradiated on the device simultaneously.

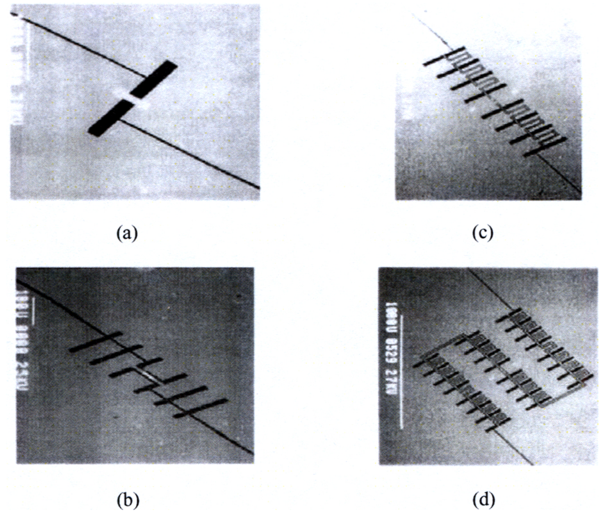


Fig. 4. SEM photographs of the fabricated single slot antenna and three kinds of the slot antenna arrays for 700 GHz wave detection.

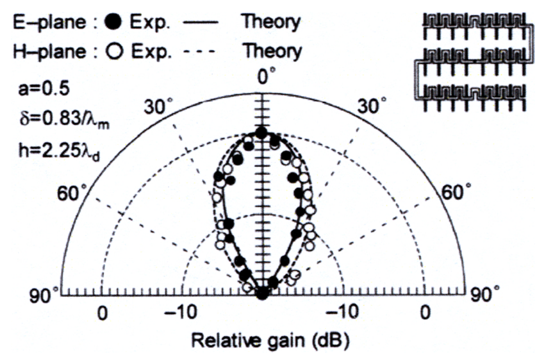


Fig. 5. Incident angle dependence of detected voltage, when the 700GHz wave irradiated on the two-dimensional 8 × 3 slot antenna arrays.

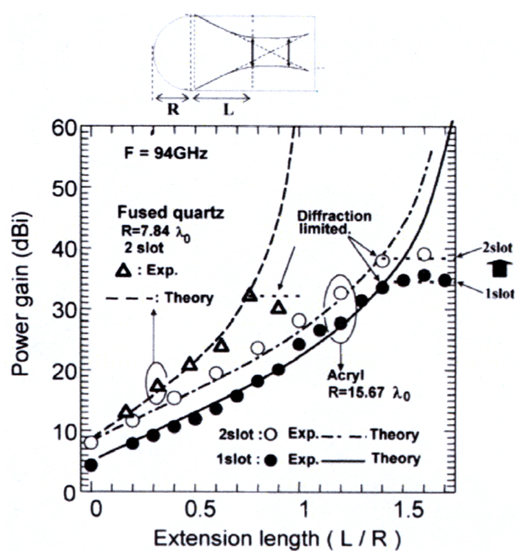


Fig. 6. Relationship between the power gain of the extended hemispherical lens coupled double slot antenna and the extension length measured at 94GHz.

proportional to the square of the irradiated wave length. The sensitivity of the device would be improved by improving the contact condition between gold film and Ge film at the point contact area [1]. In the experiments, we improve the device sensitivity by increasing the power gain of the antenna.

C. Improvement of the sensitivity of the device

The sensitivity of the device was increased by using the slot antenna arrays. Figure 4 shows the SEM photographs of the fabricated single slot antenna and three kinds of slot antenna arrays for 700GHz wave detection. The antenna gain increased with the increase in the number of parasitic slots. The gain also increased by coupling detector with the slot antenna arrays fed by CPW. The antenna gain further increased by coupling the detector with two-dimensional slot antenna arrays fed by CPW. The power gain of the antenna increased up to 13dBi when the device was coupled with the 8 × 3 slot antenna arrays fed by CPW [2].

Figure 5 shows the antenna pattern of the device for 700GHz radiation. The NEI of the device increased up to 3×10^{-6} W/m^2.

The sensitivity of the device also improved by coupling the slot antenna coupled warm carrier device with the extended hemispherical lens [3]. Figure 6 shows the relationship between

the power gain of the extended hemispherical lens coupled double slot antenna and the extension length measured at 94GHz. It is found that the power gain of around 35dBi is obtained when the extension length reaches the focal region. Figure 7 shows the antenna patterns of the device with and without the lens.

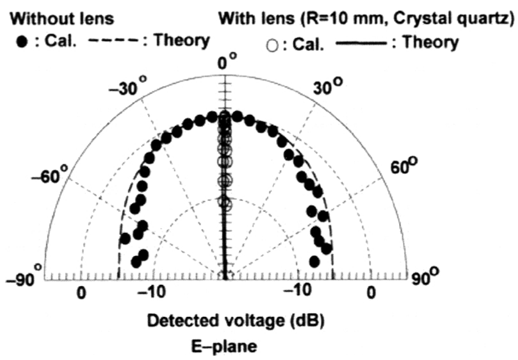


Fig. 7. Incident angle dependence of detected voltage, when the 700GHz wave irradiated on the hemispherical lens coupled double slot antenna.

III. Conclusion

A slot antenna coupled warm carrier THz radiation detectors were fabricated using the microfabrication technique, and the receiving properties were measured in the THz frequency region. In this paper the results obtained at 700GHz was described. However, the same antenna gain was obtained at 4.5GHz, 94GHz, 700GHz, 2.5THz and 28THz. The detecting properties of the warm carrier device have been discussed at 94GHz and 700GHz. Further expansion of the operating frequency of the thin film warm carrier device is under examination. Harmonic mixing experiments using the point contact warm carrier device has been demonstrated at 28THz.

References

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