# Effects of Metal V-grooved Waveguide gap width on super focusing of high efficient THz waves using laser chaos

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**Abstract**–The generation of a wide-range THz wave is investigated from a photoconductive antenna excited using a chaotic oscillation multimode semiconductor laser with optical delayed feedback by an external mirror. The stable THz wave is obtained from the multimode-laser diode excited photoconductive antenna by using a laser chaos. For a high sensitive detection, a metal V-grooved waveguide (MVG) is also used. As the MVG gap is narrower from 200 to  $20[\mu \text{ m}]$ , the detected signal is increased about twice. And also we try to THz spectroscopy oil and water.

## 1. Introduction

Generation of a stable wide-range THz Wave using a chaotic oscillation in a multimode semiconductor laser with an optical delayed feedback by the external mirror is investigated. A mode-locked Ti:sapphire laser is frequently used to excite the Voltage-biased photoconductive antenna (PA). But it is a high cost system. A multimode semiconductor laser is also used to excite



Fig.1 Metal V grooved waveguide with variable gap width.



Fig.2 Experimental Setup for the MVG gap width effects.

the antenna1,2). This system is low cost but a spectrum of generated THz wave is essentially line spectrum with a frequency interval between longitudinal modes of a semiconductor laser. And also time series of THz wave is not stable since mode hopping in multimode semiconductor lasers suddenly occurs.

We propose to use a chaotic oscillation of a semiconductor laser in order to obtain stable low cost continuously wide range THz wave. And a Metal V grooved Wave guide (MVG) is also used to detect the THz waves effectively. In this paper we investigate the dependence of the THz signals on the gap MVG width. (Fig.1)

## 2. Experimental Setup

Experimental setup is shown in Fig.2. A semiconductor laser (780nm, ROHM, RLD78PPY6) is operated in longitudinal multimode with a frequency interval of 43GHz between longitudinal modes without an external



mirror under the condition of *I*op (operation current)  $\leq$  120 mA. The output power is fed back into laser via the external mirror (R<sub>3</sub>). Fed back rate is denoted by the effective reflectivity  $R_{3(\text{eff})}$ .

## $R_{3(\text{eff})} = R_3 R_{\text{BS1}}^2,$

where  $R_3$  is the reflectivity of the external mirror(M<sub>3</sub>), and  $R_{BS1}$  is the reflectivity of BS<sub>1</sub>. In this experiments, we

fixed delayed fed back rate to 5%.

The emitter bowtie PA was applied an AC voltage of 100  $V_{pp}$  with a frequency of 40 kHz for lock-in detection. Irradiate laser power to the emitter PA and detector PA are 12.2 and 10.8 mW, respectively. The sub-THz radiation which traveled in free space was focused on the detector PA. Usually, Si lens is used for the PA, but we propose to use MVG. The photocurrent induced in the

detector bowtie PA was detected by the lock-in amplifier with a time constant of 300 ms. The signal, which is obtained as a function of the delay time, is a cross correlation between the sub-THz wave electric field and the exciting laser intensity.

#### **3. Experimental Results**



Detected signals are shown in Fig. 3. Since we use laser chaos, the both detected signals are stable. The amplitude of detected signal is 87.8 pA<sub>pp</sub> for  $\Delta x = 20 \ \mu\text{m}$ , which is enhanced about twice compared to the condition of  $\Delta x = 500 \ \mu\text{m}$ .

Dependence of the detected signal amplitude on the MVG gap width is shown in Fig.4. A red dashed line is the fitting line,

 $\ln y = -20.5 + -0.104 \ln \Delta x.$ 

where y is detected THz signal amplitude (peak to peak). Theoretical y is proportional to  $\Delta x^{-1/2}$ . In this experiment results, it is little bit small enhancement. One of the reason is machining accuracy. However, from  $\Delta x = 500$  to 20 µm, the detected signal is enhanced monotonically increasing beyond diffraction limit. In our system, the diffraction limit is 3mm which is corresponding to 0.1THz.

# 4. Conclusions

Using laser chaos THz signal is stabilized. And using MVG the detected signal is enhanced. From  $\Delta x = 20$  to 200 µm, the detected signal is enhanced as the MVG gap width is narrower. Experimental Results

## Acknowledgments

This research and development work partially supported by the Collaborative Research Based on Industrial Demand from Japan Science and Technology Agency, JST. Project name: Development of Super Sensitive Electro-Optics Sampling Scheme for Terahertz Waves and the MIC/SCOPE # 165005001.

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