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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[μm], 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 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.

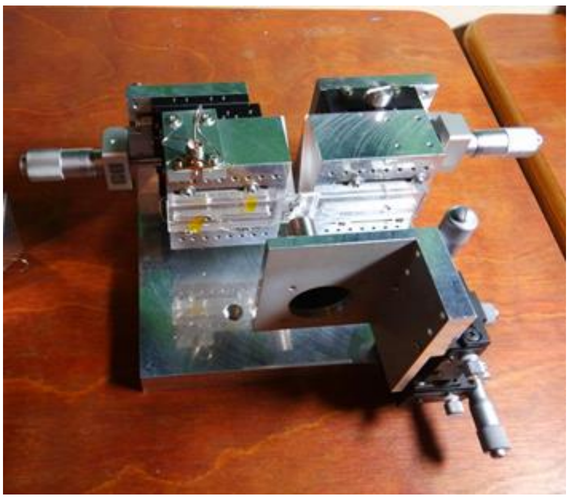

Fig.1 Metal V grooved waveguide with variable gap width.

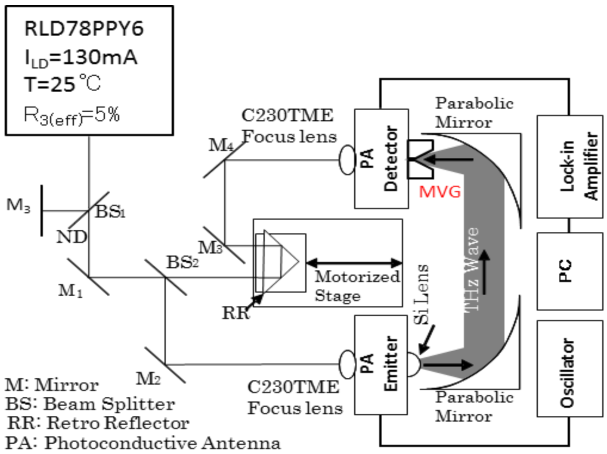

Fig.2 Experimental Setup for the MVG gap width effects.

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

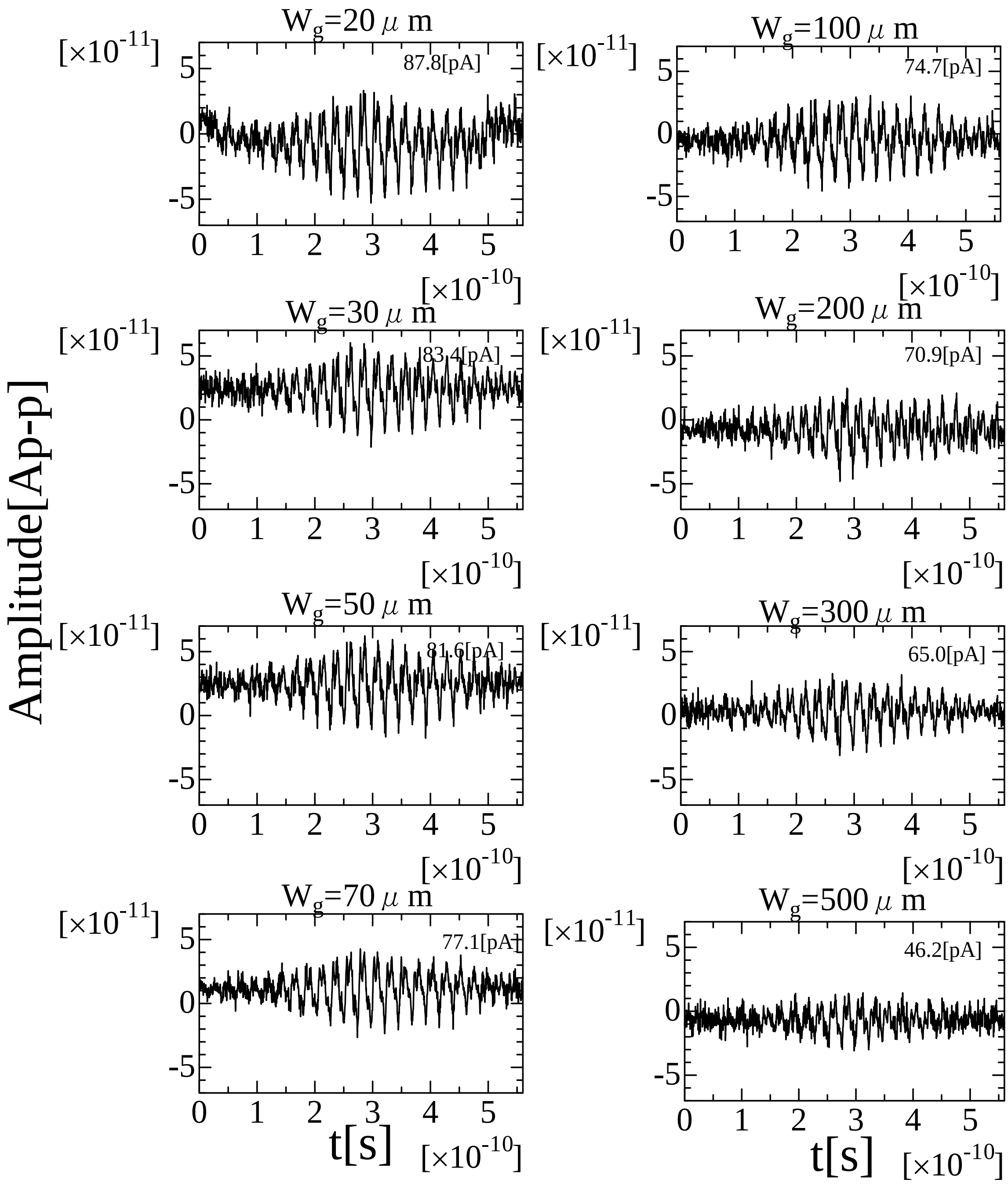

Fig.3 Time series of THz waves. MVG gap width Δx = 20 μm, to 500 μm.

mirror under the condition of Iop (operation current) ≦ 120 mA. The output power is fed back into laser via the external mirror (R_3). Fed back rate is denoted by the effective reflectivity $R_{3(eff)}$.

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

where R_3 is the reflectivity of the external mirror(M_3), and R_{BS1} is the reflectivity of BS_1. 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

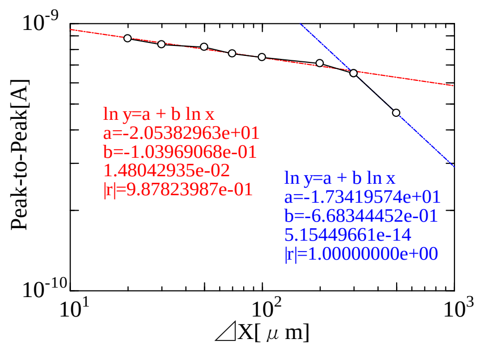

Fig.4 Dependence of MVG gap widths to Signal Amplitudes. A red dashed line is the fitting line from Δx=20μm to 300 μm . A red dashed line is the fitting line from Δx=20μm to 300 μm .

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_{pp} for $\varDelta x$ = 20 μm, which is enhanced about twice compared to the condition of $\varDelta x$ = 500 μm.

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

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

where y is detected THz signal amplitude (peak to peak) . Theoretical y is proportional to $\varDelta x^{-1/2}$. In this experiment results, it is little bit small enhancement. One of the reason is machining accuracy. However, from $\varDelta x$ = 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 Δx = 20 to 200 μm, the detected signal is enhanced as the MVG gap width is narrower. Experimental Results

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