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High efficient THz spectroscopy systems using a laser chaos and a metal V grooved waveguide

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Abstract– Generation of a wide-range and stable THz waves from a photoconductive antenna excited by a multimode semiconductor chaotic oscillation laser with an optical delayed feedback using an external mirror is investigated. A Metal V grooved Wave guide is also used to detect the THz waves effectively.

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 antenna[1-2]. This system is cheap 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 hopes in multimode semiconductor lasers suddenly occur.

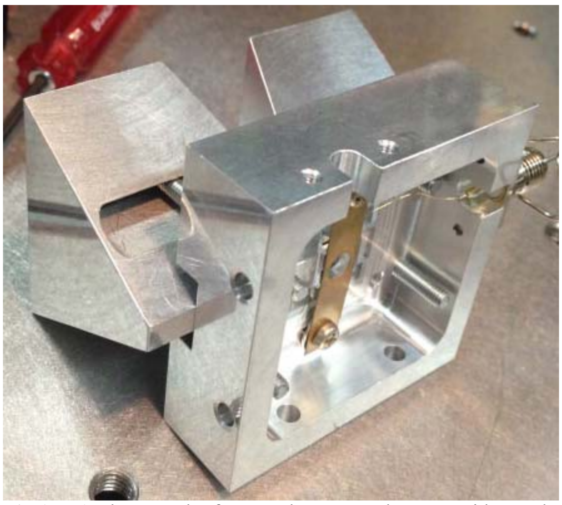

Fig.1 A Photograph of a Meta l V grooved Waveguide. angle of aperture is 18°

We propose to use a chaotic oscillation of a semiconductor laser in order to obtain stable cheap 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.(Fig.1)

2. Experimental Setup

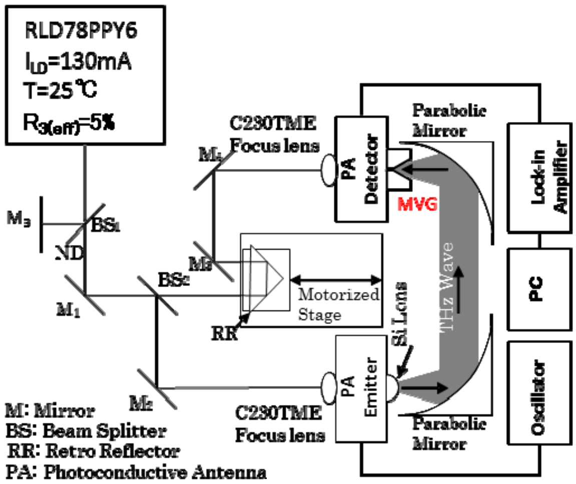

Fig.2 experimental setup

A semiconductor laser (780nm, ROHM, RLD78PPY6) is operated longitudinally multimode with a frequency interval of 43GHz between longitudinal modes without an external mirror (M_3) under the condition of Iop（operation current）≦120mA. The output power is fed back into laser via the external mirror (R_3). Fed back rate is denoted by the effective reflectivity $R_{3(eff)}=R_{BS1}{}^2R_3$, where R_{BS1} is a reflectivity of BS_1 and R_3 is a reflectivity of M_3. The emitter bowtie PA was applied with an AC voltage of 100 Vpp with a frequency of 40 kHz for lock-in detection. The sub-THz radiation which traveled in free space was focused on the detector PA. The photocurrent induced in the detector bowtie PA was detected by the lock-in amplifier with a time constant of 300 ms. The signal 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.

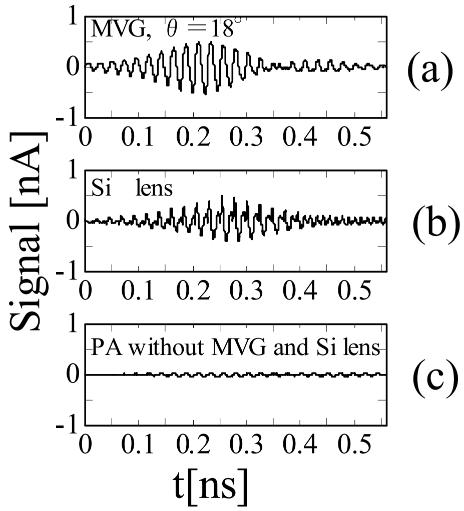

Fig.3 Time series of THz waves detected by using (a)MVG, θ =18° , (b) Si lens and (c) solitary PA without MVG and Si lens.

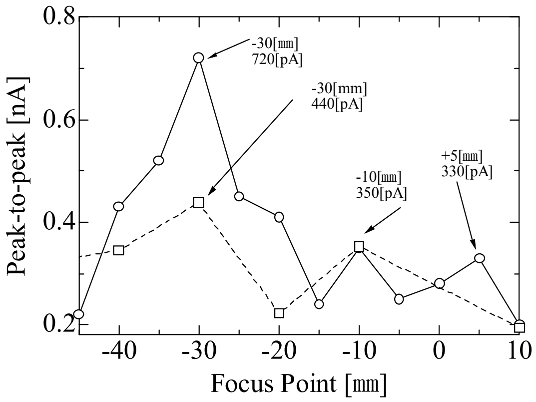

Fig.4 A dependence of focus point for detected THz output power. Dashed line and circle dot indicate using Si lens case, solid line and rectangular dot indicate using MVG case. In this figure, θ =18° and a gap width is fixed 72 μ m.

3. Experimental Results

The time series of generated THz wave are shown in Fig.3. In these figures, an off axial focus length (EFL) of condensing parabolic mirror is fixed 2 inch and $R_{3(eff)}$ is fixed 5%. From top to bottom, THz waves are detected by using (a)MVG, θ =18° , (b) Si lens, (c)Solitary PA without MVG and Si lens. MVG is mounted back side of PA, in this layout THz wave is diverged in the LT-GaAS substrate. However the detected signal is as high as using Si Lens. It suggests that MVG enhanced THz electric field by super-focusing.

Then an off axial focus length of condensing parabolic mirror is tested from 2 to 6 inch. The maximum signal is obtained in the case of EFL=4 inch. A dependence of focus point for detected THz output power is indicated in Fig.4. The maximum powers are detected at the position of -30mm, which is deeply inside of parallel wave guide side. The maximum current using Si lens is 440[pA]. Using MVG, that is enhanced to 720 [pA] which is correspond about 1.6 times compare with using Si lens. In this system MVG is mounted on the opposite side of PA, then THz signal is usually scattered in LT-GaAs substrate and decreased. And also a gap width of parallel waveguide is fixed 72 μ m, which is very narrow size compared with THz wave length. It suggests that MVG enhanced THz electric field by super-focusing beyond scattering in LT-GaAs substrate.

The detected THz waves signals using Si lens is shown in Fig.5. (a)～(c) using laser chaos,(d)～(f) using c.w. laser. (a) and (d) are time series, (b) and (e) are FFTs, and (c) and (f) are S/N.

The p-p Amplitude of generated THz signal using Si lens and laser chaos is 440[pA], on the other hand using a c.w. laser, that is 270 [pA] and this signal is not stable and noisy. THz signal is enhanced about 1.6 times using a laser chaos. The spectrum width is defined as level 10 of signal to noise ratio. In the case of c.w, laser it is limited below 0.26THz, on the other hand it is extend to 0.51THz using a laser chaos.

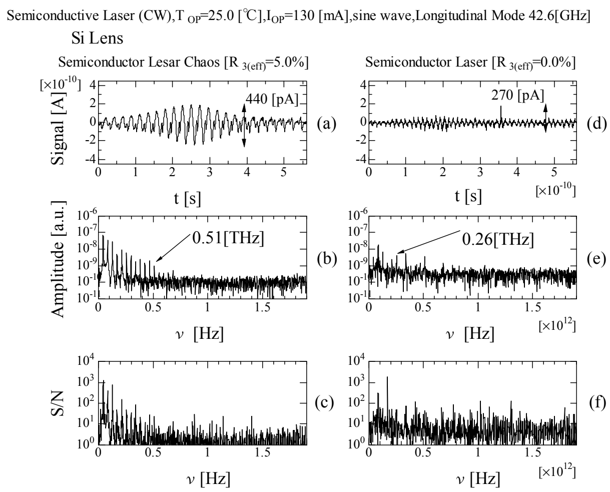

Fig.5 Detected THz waves signals using Si lens. (a)～(c) using laser chaos,(d)～(f) using c.w. laser. (a) and (d) are time series, (b) and (e) are FFTs, and (c) and (f) are S/N.

The detected THz waves signals using MVG is shown in Fig.6. The p-p Amplitude of generated THz signal using Si lens and laser chaos is 720[pA], on the other hand using a c.w. laser, that is 72 [pA] and this signal is not stable and noisy. THz signal is enhanced about 10 times using a laser chaos and also 1.6times compared with Si lens. The spectrum width is defined as level 10 of signal to noise ratio. In the case of c.w, laser it is limited below 0.13THz, on the other hand it is extend to 0.47THz using a laser chaos.

4. Summary

A stable and wide range THz wave is generated using a laser chaos. The detected THz signal is also enhanced using a metal V grooved wave guide.

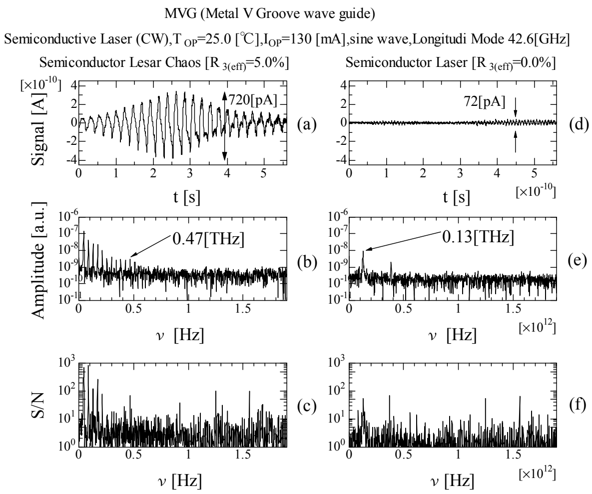

Fig.7 Detected THz waves signals using MVG. (a)～(c) using laser chaos,(d)～(f) using c.w. laser. (a) and (d) are time series, (b) and (e) are FFTs, and (c) and (f) are S/N.

References

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