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## Generation of wide range and stable THz waves using a semiconductor laser chaos and a high bias voltage

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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 high bias voltage is also used to generate wide range THz wave. Near to 1THz THz wave is obtained using this system.

### 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. But it is a high cost system. A multimode semiconductor laser is also used to excite the antenna<sup>1-4</sup>. 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 THz spectrum is limited below 0.5THz. And also time series of THz wave is not stable since mode hops in multimode semiconductor lasers suddenly occur.

We propose to use a chaotic oscillation of a semiconductor laser in order to obtain stable cheap continuously wide range THz wave. And a high bias voltage is also used to generate wide range THz waves in this paper.

### 2. Experimental Setup

Experimental setup is shown in Fig.1. A semiconductor laser (780nm, ROHM, RLD78PPY6) is operated longitudinally multimode with a frequency interval of 43GHz between longitudinal modes without an external

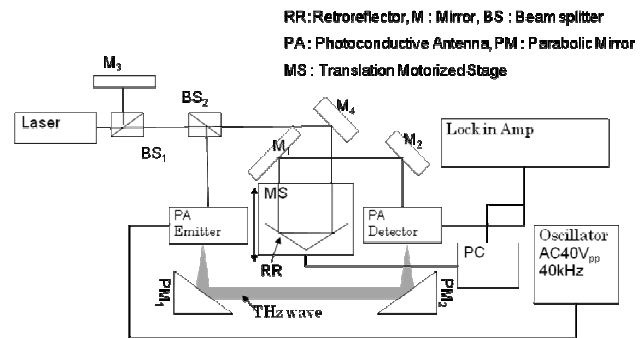


Fig.1 Experimental Setup

mirror ( $M_3$ ) under the condition of  $I_{op}$  (operation current)  $\leq 120$ mA. But in the case of  $I_{op} > 120$ mA, this laser is operated longitudinally single mode. The output power is fed back into laser via the external mirror. Fed back rate is denoted by the effective reflectivity ( $R_{3(eff)} = R_1^2 R_3$ ), where  $R_1$  is the reflectivity of  $BS_1$  and  $R_3$  is the reflectivity of external mirror  $M_3$ . The emitter PA was applied with an ac voltage of 40 Vpp with a frequency of 40 kHz for lock-in detection in this paper. In our previous system this bias voltage is 20Vpp and THz spectra around 1THz are covered with noise level. The sub-THz radiation which traveled in free space was focused on the detector photoconductive antenna (PA). The photocurrent induced in the detector 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.

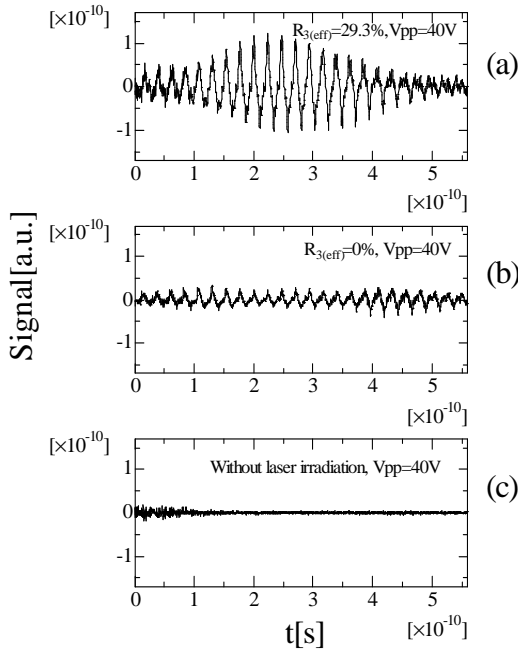


Fig.2 Time series of the THz waves

### 3. Experimental Results

The time series of generated THz wave are shown in Fig.2. From top to bottom  $R_{3(\text{eff})}$  is (a)29.3% and (b)0% . Noise level is shown in Fig.2(c) in which laser output power is not irradiated to the photoconductive antenna. The output power of laser is fluctuate with a optical delayed feedback and the generated THz wave is stable as is shown Fig.2(a). Otherwise the generate THz wave is

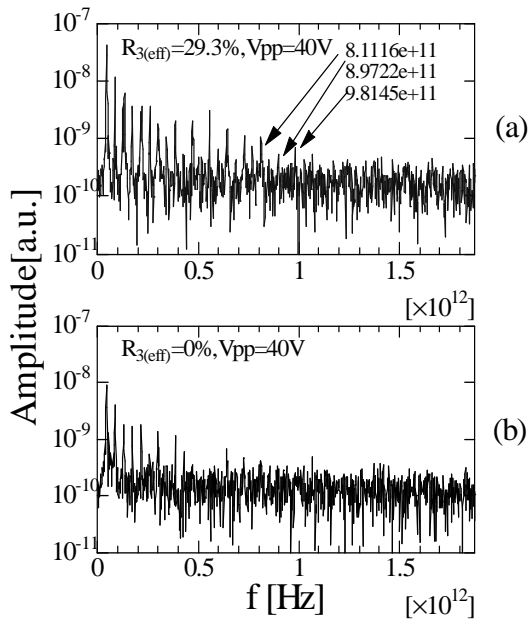


Fig.3 THz spectra

not stable in the case of a CW steady state laser excitation of photoconductive antenna as is shown in Fig.2(b).

The noise level of this system is given in Fig.2(c), in which the emitter photoconductive antenna is not irradiated by the laser output power.

The THz spectra are shown in Fig.3, in which  $I_{\text{op}}$  is fixed at 120[mA]. The laser is operated multimode longitudinally without external mirror and THz wave is obtained under CW laser operation ( $R_{3(\text{eff})}=0\%$ ). In this case the THz spectrum is limited under 0.5 THz and the THz signal (a current of photoconductive antenna) is not stable. As the feedback rate is larger, the laser spectrum is broadened and a laser oscillates chaotically. In the case of  $R_{3(\text{eff})}$  is 29.3% ( in a chaotic oscillation region of a laser), the higher frequency THz spectrum near to 1THz is obtained and an amplitude is also stronger than that of CW laser .

### 4. Conclusion

A stable and wide range THz wave is generated using a laser chaos. Optical alignment is also easy using an optical fiber.

### References

- [1] M. Tani, S. Matsuura, K. Sakai, and M. Hangyo : IEEE Microwave Guid. Wave Lett. 7, 282(1997)
- [2] O. Morikawa, M. Tonouchi, M. Tani, K. Sakai, and M. Hangyo : Jpn. J. Appl. Phys. **38**, 1338(1999)
- [3] O. Morikawa, M. Tonouchi, and M. Hangyo : Appl. Phys. Lett. **75**, 3772(1999)
- O. Morikawa, M. Tonouchi, and M. Hangyo : Appl. Phys. Lett. **76**, 1519(2001)