Generation of a stable THz wave using a laser chaos

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Abstract– Generation of a stable THz Wave using a chaotic oscillation in a multimode semiconductor laser with an optical delayed feedback by the external mirror is investigated. In this paper, the spectrum of laser chaos is compared with that of the CW steady state oscillation, and the broad spectrum is confirmed in the case of chaotic oscillation. Stabilization and the wide spectrum of THz waves are also obtained in the case of using a chaotic laser compared with that of using a CW steady state laser.

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[1-4]. 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 hopes 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.

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 mirror (R_{ex}) under the condition of I_{op} (operation current) <120mA. But in the case of I_{op}>120mA, this laser is operated longitudinally single mode. The output power is about 100mW under C.W. operation at a fixed current 140mA. The output power is fed back into laser via the external mirror. Fed back rate is denoted by the effective reflectivity ($R_{3(eff)}=T^2R_{ex}$), where T is the transmission coefficient of BS1. Separated laser

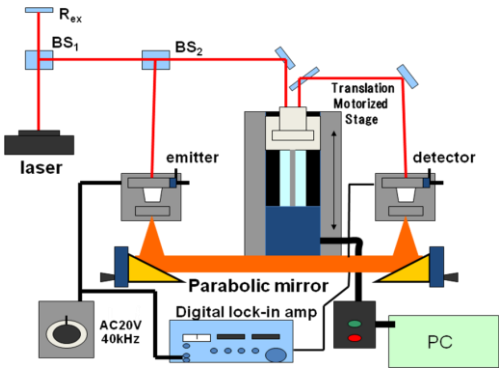

Fig.1

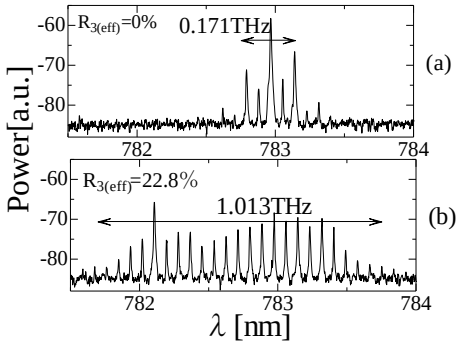

Fig.2

output power is introduced to THz-TDS system.

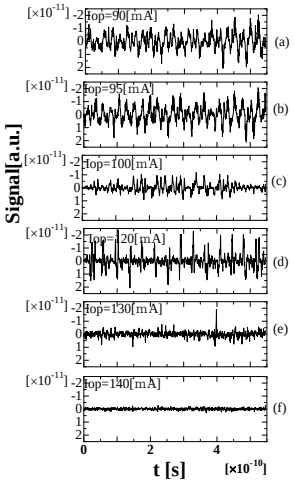

Fig.3

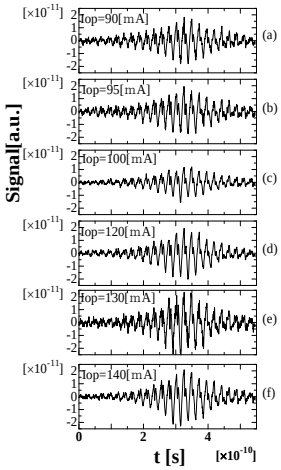

Fig.4

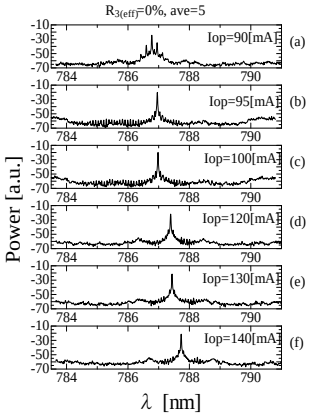

Fig.7

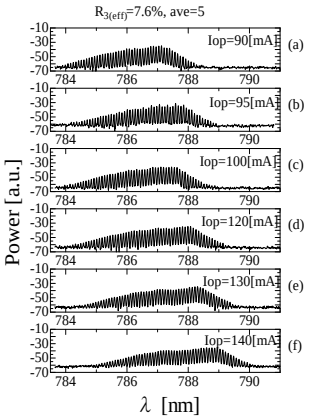

Fig.8

3. RESULTS

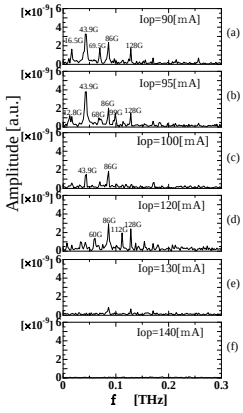

Fig.5

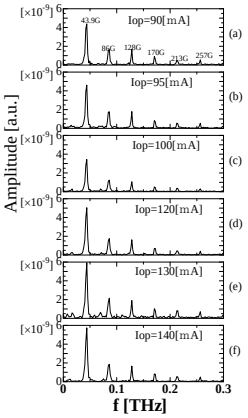

Fig.6

The laser spectrum is shown in Fig.2, in which I_{op} is fixed at 110[mA]. The laser is operated multimode longitudinal mode without external mirror and frequency difference is about 0.171[THz] between the most far modes (Fig.2(a)). As the feedback rate is larger, the laser spectrum is broadened. In the case of $R_{3(eff)}$ is 22.8%, the spectrum width is about 1.013[THz] which is about seven times as wide as that of solitary laser (Fig.2(b)).

The stability of generated THz wave by using a laser chaos is better than that by using solitary laser. In the case of chaotic laser, if the alignment is perfect, the THz wave is always generated. In the case of CW steady state laser, however, the THz wave is not always generated even if the perfect alignment.

Time series of THz waves using CW steady state laser are shown in Fig.3, when a operation current (I_{op}) is changed from 90[mA] to 140[mA]. In the case of CW steady state laser, if the semiconductor laser is operated in a multimode, generated THz wave is not always stable because of sudden mode hops. As increase the operation current, the laser oscillates in a single mode. Under the condition of the operation current is 170[mA], which is the rated current of RLD78PPY6, a THz wave is not generated completely. On the other hand, a optical delayed feedback is added with a external mirror, whose effective reflectivity ($R_{(3eff)}$) is 7.6%, and a semiconductor laser is operated in a chaotic oscillation, generated THz wave is stable, as is shown Fig.4, even if the operation current is changed from 90[mA] to 140[mA].

Figure 5 shows the Fourier transformations of generated THz waves which are correspond to Fig.3. Since temporal wave forms of THz waves are not stable, spectra of THz waves using a CW laser are noisy. Generated THz spectra using a chaotic laser are shown in Fig.6. Even if the operation current is changed, spectra of generated THz waves are stable and almost same. And highest frequency of generated THz wave is about 257[GHz] which is six times as high as fundamental THz spectrum (43[GHz]) under the condition of $R_{3(eff)}$=7.6%.

Laser spectra are shown in Fig.7, in the case of solitary laser, the laser mode becomes to single mode as the operation current increases. And laser modes are stable in a short time (second order) but mode hops suddenly occur. If the optical delayed feedback is added to the solitary laser ($R_{3(eff)}$=7.6%), laser mode fluctuate strongly, but the averaged laser modes are stable even if operation current is changed and generated THz waves are stable. (Fig.8)

4. SUMMARY

Stable, cheap and wide range THz wave is generated by using laser chaos.

References

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