Development of CW Terahertz Time Domain Spectroscopy System Based on 650-nm Chaotic Multimode Semiconductor Laser

J. J. Li[1], V. K. Mag-usara[1], V. C. Agulto[1], I. S. Ohta[2], F. Kuwashima[3], M. Yoshimura[1], and M. Nakajima[3]

[1] Institute of Laser Engineering, Osaka University, [2] Department of Physics, Konan University,
[3] Department of Electrical and Electronic Engineering, Fukui University of Technology
E-mail: lijiajun@ile.osaka-u.ac.jp

1. Introduction

Terahertz time-domain spectroscopy (THz-TDS) has been applied in various material investigations for a wide range of research fields [1-7]. Typically, femtosecond laser is used as the light source to excite and probe the photoconductive antenna (PCA) devices for THz generation and detection in THz-TDS systems. Because femtosecond lasers are expensive, the cost of THz-TDS systems is also very high. A low cost light source option is the multimode continuous wave (CW) laser, which can also be used to generate THz radiation in the PCA [1]. In such case, the THz spectrum is determined by the longitudinal mode of the laser. However, the sensitivity of the multimode laser to temperature fluctuations often leads to mode-hopping, which results to unstable and insufficient THz signal strength. Incorporating an optical feedback system to the multimode laser creates a chaotic laser source, which has been demonstrated to enhance the stability and the intensity of CW THz radiation [1].

In the previous work of F. Kuwashima *et al.*, chaotic oscillations were produced using a 780-nm multimode laser diode (MLD) and suitable optics. For this study, we converted a 650-nm MLD into a chaotic light source for THz generation and detection in a CW THz-TDS system. The 650-nm semiconductor laser diode, which is ubiquitous particularly in DVD production but not in THz-TDS, is inexpensive and has the additional advantage of short periods of longitudinal modes.

2. Experiment and Results

Figure 1 shows the schematic of the THz-TDS setup. The light source is a 650-nm multimode laser diode (input current: 110 mA, thermostat setting: 25 ℃). A simple optical feedback system consisting of a flat mirror and a beam splitter was built in front of the semiconductor MLD to create the chaotic light source, which was subsequently used to irradiate the spiral PCA emitter and detector with tightly focused laser beams at 5.6 mW and 6.2 mW, respectively.

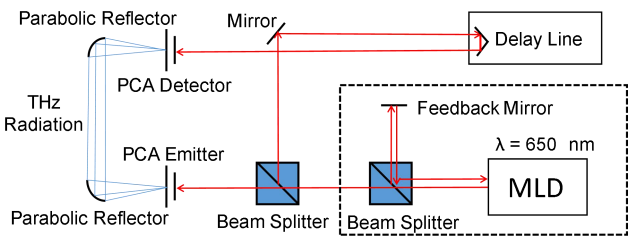

Fig. 1 Schematic of the CW THz-TDS with chaotic laser.

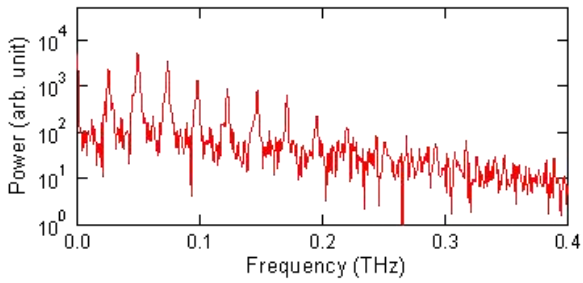

Fig. 2 The Fourier transformed CW THz spectrum by THz Time-domain spectroscopy using the 650-nm chaotic laser with 0.025-THz interval between modes.

Figure 2 shows the experimentally observed Fourier transformed spectrum, which is a frequency comb with mode interval of 0.025 THz, the narrowest mode spacing observed so far in CW THz-TDS. This narrow interval is highly favorable for sub-100 GHz electromagnetic response measurements in evaluating 5G and 6G components.

3. Conclusions

We developed a THz-TDS system using a chaotic light source constructed from a 650-nm semiconductor laser diode, and consequently demonstrated the generation of CW THz radiation with comb-like frequency spectrum and very narrow-spaced modes. Such a semiconductor chaotic laser-based measurement system with 0.025-THz resolution is highly promising for 5G and beyond 5G applications.

References

[1] F. Kuwashima et al., Opt. Express 28, 24833 (2020).
[2] V. C. Agulto, et.al., Appl. Phys. Lett. 118, 042101 (2021).
[3]. K. Yamaguchi, et al., Phys. Rev. B 92, 064404 (2015).
[4]. T. Matsui, et.al., Jpn. J. Appl. Phys. 55, 03DC12 (2016).
[5]. M. Nakajima, et al., J. of Lumin. 129, 1802-1805 (2009).
[6]. M. Ota, et.al., Appl. Phys. Express 14, 026503 (2021).
[7] S. Ohkoshi, et.al.,Adv. Mater. 32, 2004897 (2020).