Portable 1.55μ m Terahertz Spectrometer and Imaging System

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***Abstract*—We demonstrate a portable terahertz (THz) spectrometer and imaging system. Absorption lines of water vapor in the free space are clearly observed by using the THz system. A THz imaging of a medical knife behind a poly-ethylene is finely measured by the same THz system as well.**

I. INTRODUCTION

COMPACT, lightweight, and cost-effective terahertz (THz) spectroscopy and imaging systems have been gradually required for utilizing in the outdoors or moving situations such as the fields of security, non-invasive testing, food and agricultural goods quality control, and environment monitoring. Fiber-coupled THz systems can be one of solutions. They are lower cost, higher stability, portable THz systems as compared to free-space THz systems, since they have movable THz emitters and detectors [1]. Recently, compact THz emitting and detecting systems have been reported. Due to the utility of 1.55μm optical components, compact size, and cost-effectiveness, InGaAs-based fiber-coupled terahertz time-domain spectroscopy (THz-TDS) systems are considered promising [1]-[3]. In addition, compact and broadband continuous-wave (CW) THz optical beat sources, such as a monolithic dual-mode distributed feedback semiconductor laser and a 1.55 μm detuned dual-mode laser diode have been also developed to realize hand-held THz systems [4]-[7].

In this paper, we report a fiber-coupled InGaAs-based spectrometer and imaging system. Using the THz system, we present the experimental results of spectroscopy and imaging.

II. EXPERIMENTAL RESULTS

Our experimental setup of a fiber-coupled THz-TDS system is as in the following. It consists of a femtosecond laser with a pulse width of 70 fs, a computer-controlled delay line, an emitter module, a detector module, a 1×2 optical splitter, a dispersion-compensation fiber (DCF), a sine-wave function generator, and a lock-in amplifier. The DCF and SMF lengths in the system were tuned to compensate any pulse broadening [3].

The emitter (or detector) module depicted in Fig. 1 comprises a log-spiral antenna-integrated low-temperature grown (LTG) InGaAs photo-conductive antenna (PCA) chip on a printed circuit board (PCB), a hyper-hemi-spherical Si lens, and a fiber assembly. The fiber assembly is adjusted by a micromanipulator to couple the optical pulse signal to the active area of the PCA chip. In addition, a high-resistivity and collimating Si lens was used to reduce free-carrier absorption and to decrease the required number of THz components, such as parabolic mirrors and plastic lenses. In experiment, a free-space distance between the emitter and the detector in the THz-TDS was 65mm. The THz output power of the emitter was about 130 nW when the bias voltage, the optical average pumping power, and the emitter photocurrent were 7.3 V, 9 dBm, and 0.8 mA, respectively. Lock-in integration time and measuring time on each delay step were 100 ms and 500 ms, respectively.

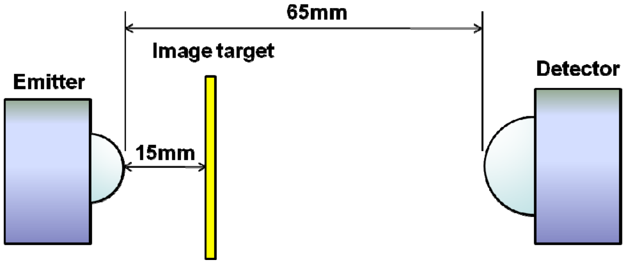

Fig. 1. Setup of THz-TDS module for measuring THz spectrum and imaging.

First of all, we measured water vapor in the free space for feasibility of the THz-TDS spectroscopy. Fig. 2 shows absorption spectrum of free space measured by using the THz-TDS system, where the time delay step and the frequency resolution are 0.1 ps and 2.44 GHz, respectively. As shown in Fig. 2, absorption lines of water vapor in the free space were clearly detected at 557, 752, 988, 1097, 1113, 1163, 1208, 1229, 1411, 1602, 1661, 1669, 1717, and 1762 GHz at the conditions of a relative humidity of about 10 % and room temperature. These results show that the THz radiation bandwidth of the THz-TDS system should be sufficiently higher than 2 THz.

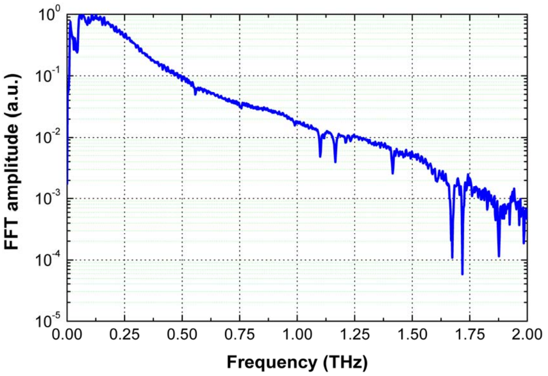

Fig. 2. Absorption spectrum of water vapor in the free space measured by using the THz-TDS system, where the time delay step and the frequency resolution are 0.1 ps and 2.44 GHz, respectively.

Then we measured the spot size of THz-wave beam along to THz radiation-direction by a knife-edge method to find an optimal position for THz imaging. With respect to the result as shown in Fig. 3, we chose an image target position of 15 mm far

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from the emitter.

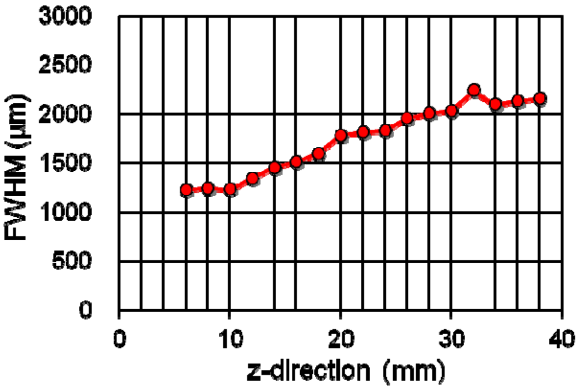

Fig. 3. Spot size of THz-wave beam along to THz radiation-direction.

Fig. 4 shows a THz imaging result of a medical knife behind a poly-ethylene with a thickness of 1 mm measured by using the THz-TDS system, where a signal-to-noise (SNR) of 300, a THz beam spot size of 1.5 mm, a cell size of 0.5×0.5 mm^2, a pixel resolution of 100×20 was set. The THz imaging of the medical knife was finely measured as in Fig. 4. We can see that the THz-TDS system should be enough an imaging system as well as a spectroscopy system.

Fig. 4. Photograph of a medical knife, and its THz image measured by using the THz-TDS system.

III. CONCLUSION

We have successfully demonstrated a fiber-coupled THz-TDS system. The THz output power of the emitter was about 130 nW when the bias voltage, the optical average pumping power, and the emitter photocurrent were 7.3 V, 9 dBm, and 0.8 mA, respectively. Under the best alignment condition, absorption lines of water vapor in the free space were clearly measured by the THz-TDS system. Moreover, we have finely measured a THz imaging of a medical knife behind a poly-ethylene by using the THz-TDS system

ACKNOWLEDGEMENTS

This work was supported by the Public welfare & Safety research program through the National Research Foundation of Korea (NRF), by the Ministry of Education, Science and Technology-grant #2010-0020822.

REFERENCES

[1] B. Sartorius, H. Roehle, H. Künzel, J. Böttcher, M. Schlak, D. Stanze, H. Venghaus, and M. Schell, “All-fiber terahertz time-domain spectrometer operating at 1.5 μm telecom wavelengths,” Optics Express 16, 9565-9570 (2008).

[2] H. Roehle, R. J. B. Dietz, H. J. Hensel, J. Böttcher, H. Künzel, D. Stanze, M. Schell, and B. Sartorius, “Next generation 1.5 μm terahertz antennas: mesa-structuring of InGaAs/InAlAs photoconductive layers,” Optics Express 18, 2296-2301 (2010).

[3] S. -P. Han, H. Ko, N. Kim, H. -C. Ryu, C. W. Lee, Y. A. Leem, D. Lee, M. Y. Jeon, S. K. Noh, H. S. Chun, and K. H. Park, “Optical fiber-coupled InGaAs-based THz time-domain spectroscopy system,” Optics Letters 36, 16, 3094-3096 (2011).

[4] N. Kim, J. Shin, E. Sim, C. W. Lee, D.-S. Yee, M. Y. Jeon, Y. Jang, and K. H. Park, “Monolithic dual-mode distributed feedback semiconductor laser for tunable continuous-wave terahertz generation”, Opt. Express 17(16), 13851-13859 (2009)

[5] N. Kim, Y. A. Leem, M. Y. Jeon, C. W. Lee, S.-P. Han, D. Lee, and K. H. Park, “Widely Tunable 1.55 um Detuned Dual Mode Laser diode for Compact Continuous-Wave THz Emitter,” ETRI Journal 33, 5, (2011).

[6] N. Kim, S.-P. Han, H. Ko, Y. A. Leem, H.-C. Ryu, C. W. Lee, D. Lee, M. Y. Jeon, S. K. Noh, and K. H. Park, “Tunable continuous-wave terahertz generation/detection with compact 1.55 μm detuned dual-mode laser diode and InGaAs based photomixer,” Opt. Express 19, 15397 (2011).

[7] K. H. Park, N. Kim, H Ko, H. -C. Ryu, J. -W. Park, S. -P. Han, and M. Y. Jeon, “Portable terahertz spectrometer with InP related semiconductor photonic devices,” Proc. SPIE Photonics West, Jan. (2012).