Development of Laser Scanning Terahertz Imaging System Using Organic Nonlinear Optical Crystal

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***Abstract*—We constructed a laser scanning terahertz (THz) imaging system for high-speed imaging by using a galvano scanner and an organic nonlinear optical crystal, DASC, as a two-dimensional THz emitter. Using this system, we succeeded in obtaining high-resolution THz images of a test sample.**

I. Introduction And Background

TERAHERTZ (THz) imaging technique has attracted much attention for many practical applications in the various fields from bio to security [1] [2]. For practical use of this technique, there are several problems to be overcome, such as a spatial resolution, imaging speed, etc. As a first step toward the practical use of THz imaging system, we have constructed a prototype of laser scanning THz imaging system using a galvano scanner and an organic nonlinear optical crystal, DAST, as a two dimensional THz emitter as shown in Fig.1 [3]. In this system, 1.56 μm femtosecond laser pulses are modulated at 2 kHz by an optical chopper and scanned over the THz emitter by using a galvano scanner. THz wave pulses which are locally generated at the laser irradiation spots transmit through a sample that is set on the emitter, and are detected by a photoconductive antenna (PCA). Therefore, we can observe a THz image of the sample by monitoring the amplitude of the THz wave pulses. In addition, the reflected laser beam from the emitter is detected as a laser reflection image by photodiode, so we can compare the THz image and laser reflection image and confirm the THz emission points. In addition, we can use this system for THz time-domain spectroscopy (THz-TDS) when the galvano scanner is fixed.

In this study, we used a DAST and a DASC crystal as a THz emitter and evaluated the system performance for THz imaging.

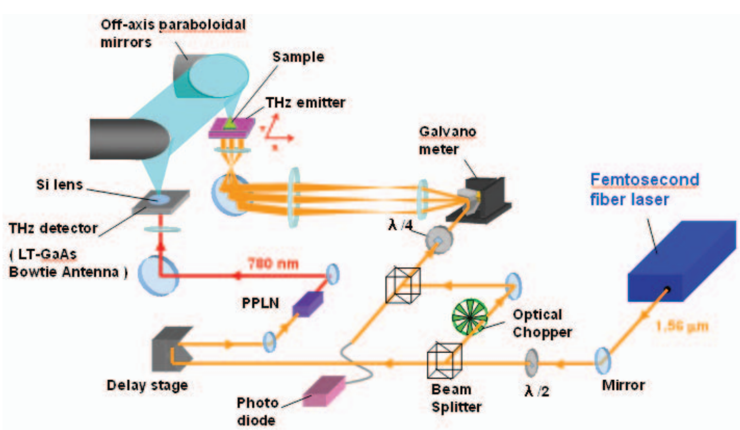
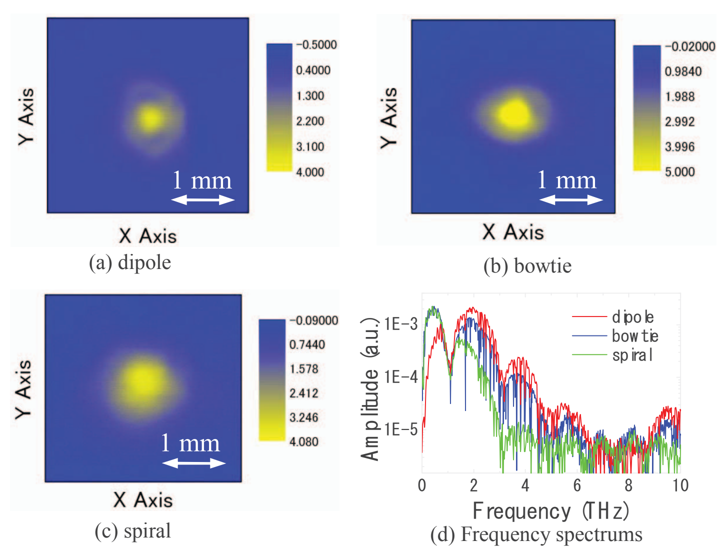


Fig.1: A schematic illustration of laser scanning THz imaging system

II. System Design And Experiment

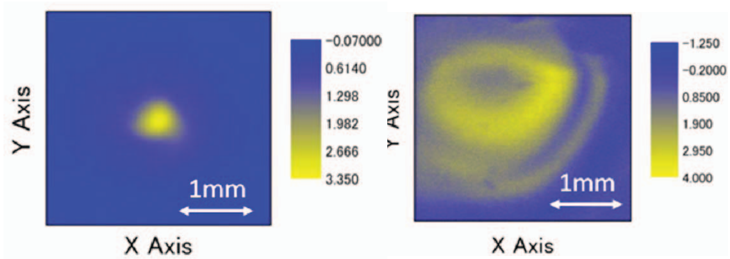
Prior to this experiment, we studied the most appropriate system model. Because we use a crystal, we must consider the fact that imaging results might be affected by the thickness and quality of the crystal. Most especially, the difference of the reflective indices at each part of the crystal may cause a decrease in the spatial resolution. Thus, we constructed a lens system which makes the laser pulses perpendicular to the emitter. We also studied the dependence of the structure of detectors. Fig.2 (a)-(c) shows the THz emission images of DAST and their frequency spectrums using a dipole, bowtie and spiral shaped detector, respectively. The ranges of detection have broadened in order of dipole, bowtie, and spiral shaped detectors. It is also understood that we can obtain the most broadband frequency range using dipole shaped detector.

DASC is one of the groups of organic nonlinear optical crystals and its optical characteristics are almost similar to those of DAST [4] [5]. Fig.3 (a) and (b) show the THz emission images of DASC when the bowtie shaped detector was focused and unfocused, respectively. It is clearly seen that the range of detection is wider when the detector is unfocused. We also observed a uniform area of THz intensity about 1.5 mm long in the emission images of DASC crystal when the detector was unfocused. As a result of these studies, we need to choose an appropriate detector which is suitable for our experiments such as THz imaging or THz-TDS.



(a) dipole (b) bowtie (c) spiral (d) Frequency spectrums

Fig.2: THz emission images of DAST crystal, using (a) dipole (b) bowtie and (c) dipole shaped detectors, and (d) comparison of frequency spectrum data obtained by these 3 detectors, respectively.



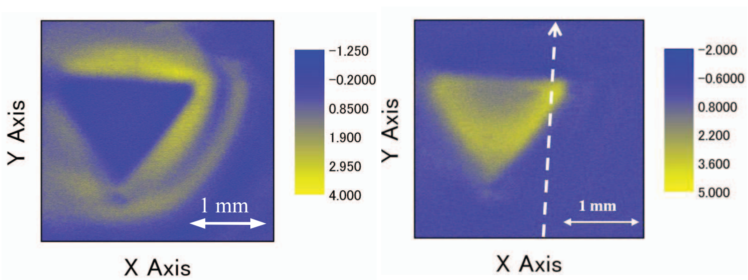
(a) focus (b) unfocus

Fig.3: THz emission images of DASC crystal when the detector was (a) focused and (b) unfocused

In this experiment, for high resolution and wide range THz imaging, the relatively-flat DASC crystal was used for a THz emitter. As a detector, the bowtie shaped PCA was used and it was unfocused for detecting wide range of THz emission.

III. Results

Fig.4 shows a THz image of a sample, 2-mm-equilateral-triangle-shaped Cu sheet, which is set on the emitter. (a) is a THz transmission image and (b) is a difference image with the reference (without the sample ; Fig.3(a)) and (b). The pixel size is 500x500 and the measurement time is 9 minutes for one image. As you can see, we could obtain a clear image of the Cu sheet. Fig.5 and Fig.6 are THz frequency spectrum of a DASC crystal and a line profile along the dashed line inserted in Fig.4, respectively. The spatial resolution reaches about 140 μm, although the main frequency is located around 0.2 THz in the broad band spectrum of the emitted THz waves. As a result, we succeeded in THz imaging with the resolution below wavelength of the emitted THz wave pulses. This is due to a near-field effect.



(a) THz transmission image (b) Difference image

Fig.4: THz images of Cu sheet using DASC crystal.

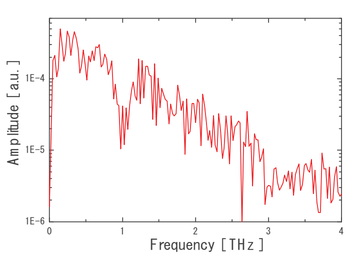


Fig.5: THz frequency spectrum of DASC crystal

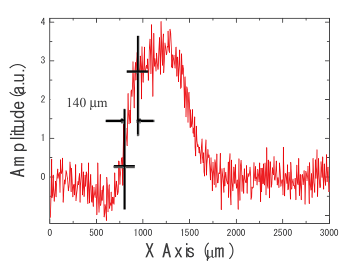


Fig.6: A line profile along the dashed line inserted in *Fig.4*

IV. Conclusion

We have developed laser scanning THz imaging system using DASC as a THz emitter and evaluated the system performance from THz imaging of the Cu sheet sample. The imaging time is 9 minutes for 500x500 pixels data, which can be shorten by using an acousto-optical modulator (AOM) instead of the optical chopper. If the laser beam is modulated by AOM at several hundreds of kHz, we will be able to obtain the THz image at the rate of 5 frames per second for 100x100 pixels. As for the spatial resolution, it is also expected to be further improved by optimizing the thickness of DASC crystal.

Acknowledgment

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