Scanning Laser Terahertz Imaging System using a 1.56 μm Femtosecond Fiber Laser

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***Abstract*—We have developed a scanning laser terahertz imaging system with 1.56 μm femtosecond fiber laser for high-speed and high resolution measurement. Using this system, we succeeded in obtaining high-resolution THz images of various samples. An imaging speed of about 47 seconds/image for 512 x 512 pixels and a spatial resolution of up to 56 μm were achieved.**

I. Introduction And Background

TERAHERTZ (THz) imaging technique has attracted much attention for various application from biology to security [1]-[4]. For practical use of this technique, there are several problems to be overcome, such as imaging speed and spatial resolution. In conventional THz imaging technique, samples were set at the focal position of THz waves and moved two-dimensionally by using mechanical stages, so it takes several hours to obtain an image. As for the spatial resolution, it is limited at most several hundreds of μm due to the diffraction limit of the THz waves. Recently, to overcome these problems, we have proposed and developed a scanning laser THz imaging system using a galvano meter and an organic nonlinear optical crystal, DASC, as a two dimensional (2D) THz emitter [5]. In this study, we tried to obtain transmitted THz images of various samples with high-resolution and high-speed measurement and evaluated the system performance.

II. Experimental Setup

Fig.1 shows a schematic drawing of the scanning laser THz imaging system. In this system, a 1.56 μm femtosecond fiber laser (TOPTICA FFS.SYS.HP: 350 mW, 110 fs, 80 MHz) is used for an optical source. At first, the laser beam is divided into two pulses; pump pulses and trigger pulses. The pump pulses are modulated at 97.5 kHz by using an acousto-optic modulator (AOM) and scanned over the 2D THz emitter, DASC (4x5x0.2 mm^3), by using the galvano meter. THz pulses that are locally generated at the laser beam irradiation spots transmit through a sample that is set directly on the emitter are detected by a low temperature (LT) glown GaAs photoconductive antenna (PCA). On the other hand, the trigger pulses are converted to 780 nm by PPLN, and then irradiated to the PCA. Therefore, we can observe a transmitted THz image of the sample by monitoring the amplitude of the THz pulses.

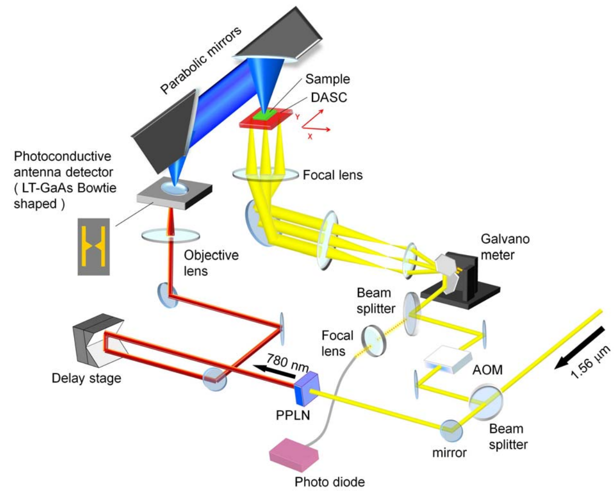

Fig.1 Schematic drawing of Scanning Laser THz Imaging System

III. System Design and Evaluation

Prior to this experiment, we carried out pre-experiment to find the best optical alignment condition to obtain THz images. Because we use a DASC crystal, as a 2D THz emitter, we must consider the fact that imaging results might be affected by the thickness and quality of the crystal. DASC is one of the groups of organic nonlinear optical crystals and its optical characteristics are almost similar to those of DAST [6]. Most especially, the anisotropic reflective index at each crystal axis may cause a distribution of THz intensity radiated from the crystal. Thus, we constructed a lens system that makes the laser pulse beam perpendicular to the crystal surface. We also tried to optimize the detector position. Since we are using a typical PCA as a detector, the observable THz imaging area could be limited. Figs. 2a and 2b show the THz radiation images of the DASC when the THz beam was focused and unfocused on the detector, respectively. As you can clearly see, the THz radiation area in the image for the unfocused position is wider than that for focused one. Furthermore, a uniform area of THz intensity about 1.5 mm long, which can be used as a canvas in the THz imaging, is obtained for the unfocused position. However, the THz amplitude and the bandwidth decrease when the detector is positioned at the unfocused point. The center frequency of generated THz waves is located around 0.4 THz for both the conditions. As a result of these studies, it was found to choose an appropriate detector position that is suitable for sample size.

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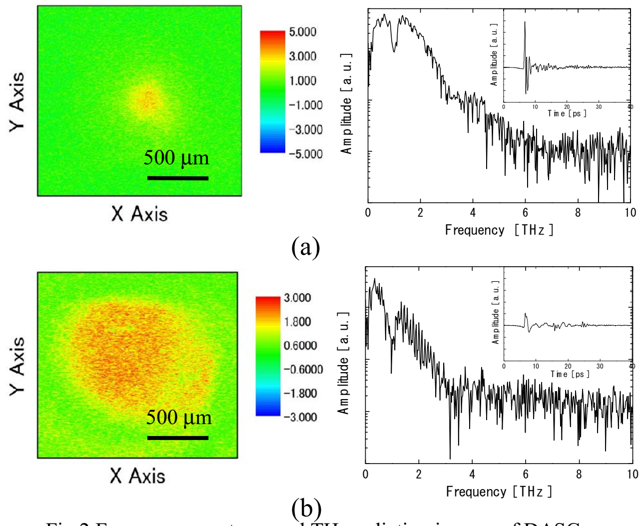

Fig.2 Frequency spectrum and THz radiation images of DASC when the detector was set at (a) focused and (b) defocused position

IV. Results

Fig.3b shows a THz transmission image of a 2-mm-equilateral-triangle-shaped cupper sheet sample. As shown here, a clearly screened image of the THz waves can be obtained by the cupper sheet. Using a differential THz image, we could observe the shape of the sample more clearly by subtracting the background THz signal, as shown in Fig. 3c.

On the other hand, THz waves are very sensitive to water, so it is interest for us to measure aqueous samples. Here, we set a human hair as shown in Fig.4a on the DASC crystal, and observed transmitted THz images. Fig.4b and Fig. 4c show a transmitted THz image and a differential image of the human hair sample, respectively. As you can see, we could observe a clear thin shape of the hair sample. It is noticed that there exist several strong THz radiation spots as well as weak THz radiation spots inside the identical hair sample. These behaviors indicate that the transmitted THz waves relate to the inner structures or internal constituent such as water of the human hair. Generally, human hair consists of keratin protein and includes 20 – 30 % of water, so further measurements by using another human hair are needed to be duplicated.

As for the system performance, those transmitted THz images are composed of 512 x 512 pixels, and the imaging speed is about 47 seconds/frame. The spatial resolution reaches up to 56 µm, although the main frequency is located around 0.4 THz in the broadband spectrum as mentioned in section III. This spatial resolution is achieved probably due to near-field effect.

V. Conclusion

We fabricated a scanning laser THz imaging system and succeeded in obtaining THz images of metal and human hair samples with high-speed and high-spatial resolution. As for the hair sample, we could observe interesting THz images reflecting the information inside the hair. We believe that a further high-speed imaging (several seconds/frame) is possible by optimizing the system configuration and improving the SNR. On the other hand, we will try to make the imaging area wider by optimizing the detector's position, structure, etc. Further details about the system configuration and the experimental results will be presented.

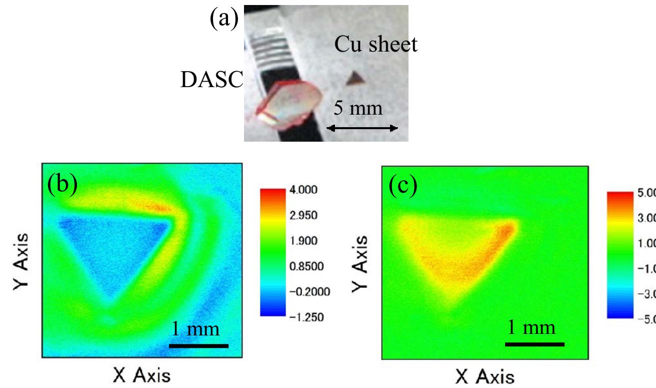

Fig.3 (a) optical image of DASC crystal and cupper sheet sample, (b) Transmitted THz image and (c) different THz image of a cupper

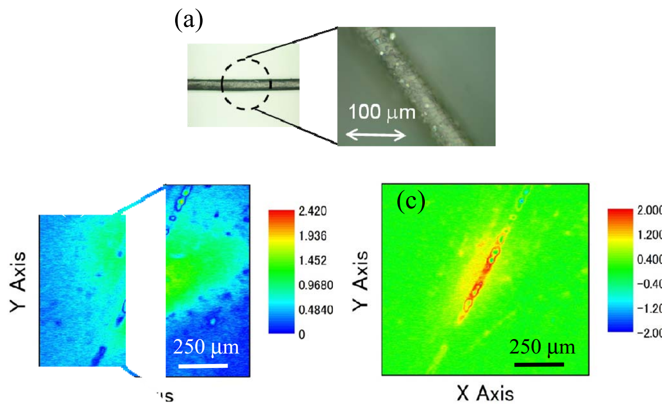

Fig.4 (a) optical image, (b) transmitted THz image and (c) different THz image of a human hair sample

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