Comparison of Image Resolution in Terahertz Pulsed and Continuous-wave Imaging Systems

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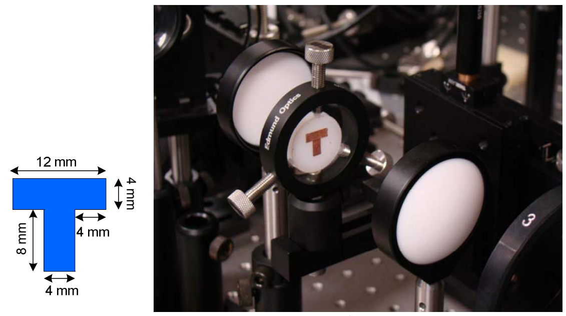
Abstract— **Continuous-wave (CW) and pulsed terahertz systems are used to take images of a "T" shape sample made of copper tape adhered on a polyethylene disc. Images are compared in terms of their resolution and contrast, and their dependencies on operation frequency, beam spot size, and scanning steps are discussed.**

I. Introduction

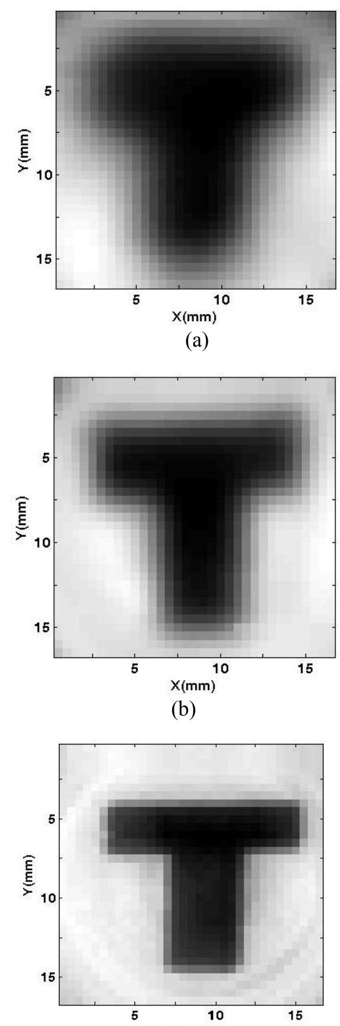
TERAHERTZ (THz) imaging is one of the most promising applications of the THz technology. The THz imaging is proposed as a complement technique to other imaging modalities such as MRI and X-ray. The first THz images from biological tissues and tooth caries were take in late 90's. It has also been shown that the THz waves can be used for cancer diagnosis application [1]-[2]. Terahertz waves can penetrate many materials and generate images with high spatial resolution. Terahertz time domain pulsed systems have been widely used for various imaging applications [3]. Continuous-wave THz systems have also been recently used for imaging applications [4].

In this paper, the pulsed and CW imaging techniques have been used to take images of a "T" shape sample made of copper tape adhered on a polyethylene disc at different frequencies and scanning step sizes. The pulsed and CW imaging methods are compared in terms of their spatial resolution and image contrast for different operation frequencies and beam spot sizes. The effect of operation frequency and the step size on the spatial resolution of the images are discussed.



(a) (b)

Fig1: (a) Schematic of the "T" shape sample, (b) Actual sample mounted on the set-up



(a) (b) (c)

Fig2. Images taken by the quasi-optical CW set up with 500 µm scanning step size and at (a) f=150GHz (λ=2mm), (b) f=450GHz (λ=666µm), (c) f=1.27 THz (λ=236µm).

II. Results

The quasi-optical CW set up consists of a backward wave oscillator (BWO) and a chain of ×2 and ×3 multipliers generating signals with frequencies between 85.4 GHz and 1.59 THz, a Golay cell detector, and a series of focusing and collimating lenses. The sample is a "T" shape made of copper tape adhered to a polyethylene disk with the thickness of 5.5 mm and the radius of 14 mm (Fig.1). The sample is mounted on an X-Y motorized translation stage for raster scan. The generated THz wave is focused on the sample using a pair of Teflon lenses with 50 mm focal length. The sample is placed at the focus of the THz beam for maximum spatial resolution.

Figure 2 shows the images taken by quasi-optical CW setup at three different frequencies and at 500 µm scanning steps in X- and Y- directions. As it can be seen from Fig. 2, the resolution of the image enhances as the operation frequency increases. This can be attributed to the decrease in the beam spot size at the focal point of the focusing lenses (see Fig. 3).

The THz pulsed system is a standard photoconductive THz time domain imaging system consists of a transmitter and a receiver photoconductive antenna. The transmitter is a

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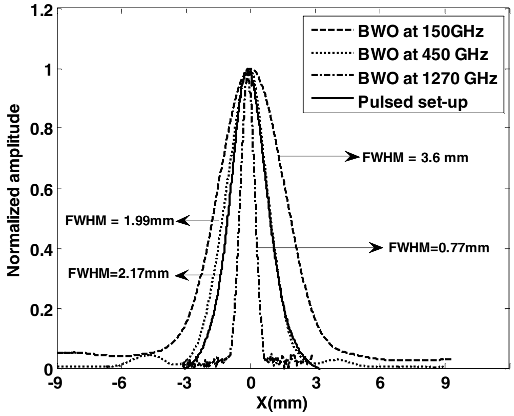


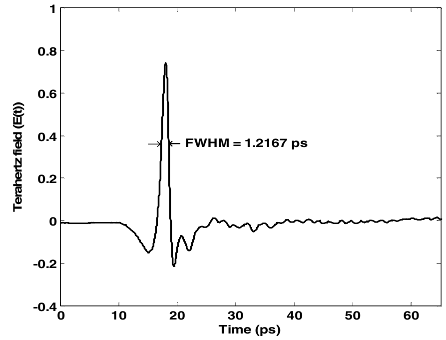
Fig3: Comparison between the beam size at the focal point of the focusing lenses for the pulsed and quasi-optical CW systems.

0.5 mm dc-biased aperture antenna on S.I. GaAs substrate. The receiver antenna is a dipole with 80 µm arm and 6 µm gap between the two arms made on a low-temperature grown GaAs substrate. The laser source is a Ti:sapphire short pulse laser with pulse duration of 100 fs and 80 MHz repetition rate. The generated THz pulse is focused on the sample using a pair of Tsurupica lenses with 50 mm focal length. The detected THz electric field and its corresponding spectrum are shown in Fig. 4.

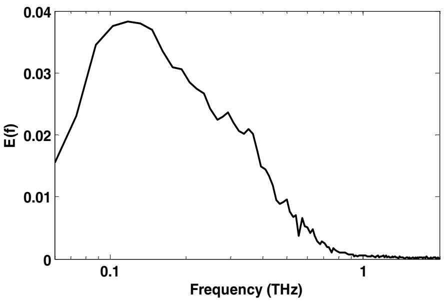
Figure 5 shows the images taken with the THz pulsed system at two different scanning step sizes. The resolution of the image taken with 250 µm step size is better than that of the image taken with 500 µm step size. Comparing the two images taken by the pulsed system and the CW system at f=450GHz with 500 µm step size, both images have the same resolution; however, the image taken by the pulsed system has a better contrast. The size of the THz pulse beam is comparable with that of the 450GHz CW signal (see Fig.3), resulting in a similar resolution for the two images.

The resolution of the image taken by the CW system at 1.27 THz is better than that of the image taken by the pulsed system. The energy of the THz pulse is concentrated at frequencies below 1 THz (Fig. 4(b)), resulting in a larger beam size at the focal point of the focusing lenses compared to that of the CW signal at 1.27 THz.

Comparing Fig. 5(a) and 5(b), it can be seen that the resolution of the image increases as the scanning step size decreases. However, the resolution of the image taken by CW system at 1.27THz frequency and 500µm step size (Fig. 2(c)) still has a better resolution compared to the image taken by the pulsed system with 250µm step size (Fig. 5(b)).

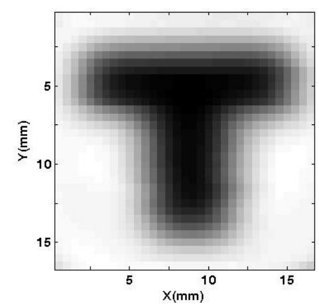


(a)

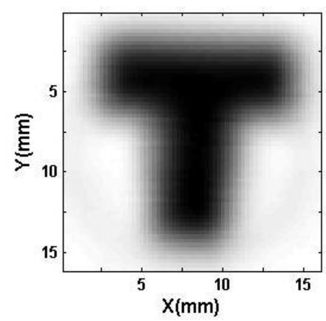


(b)

Fig4. Detected THz electric field and its corresponding spectrum in THz time domain imaging system.



(a)



(b)

Fig5. Image taken by the THz pulsed set-up with (a) 500µm scanning step size (b) 250 µm scanning step size.

III. Acknowledgement

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IV. References

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