

Rapid data acquisition in terahertz imaging

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A new data-acquisition method based on the less movement of the time-delay stage is designed. The method can clearly reduce the time used in the entire imaging process in terahertz pulse imaging. According to the experimental result, the quality of imaging remains the same as the normal method or even better. The applicability and limitation of the method are also discussed.

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Terahertz (THz) waves have the property of passing easily through many specific materials, and thus the applications of THz imaging have wide prospects in airport security checking, biological testing, nondestructive determination, and so on^[1]. Generally, A THz pulse imaging system is mainly based on a THz-time domain spectroscopy (TDS) system^[2]. In our experimental system shown in Fig. 1, the photoconductive emitter is used to generate THz radiation, which is detected effectively by electro-optic sampling^[3] with a bandwidth of 0.1–4 THz. Four off-axis parabolic mirrors are used to collect and collimate the THz radiation. At the sample point, an X-Y motorized stage controlled by a computer is used to move the sample.

For the imaging system based on THz-TDS in Fig. 1, the imaging of the sample is normally obtained point by point. Generally, for each pixel of an image, a full time-domain scan should be executed to obtain first the THz-time domain pulses. The main pulse amplitude or the main pulse position should then be identified as the gray scale reference for the current pixel^[4]. In the previous experiment, the peak-to-peak amplitude is used as the reference (see Fig. 2: positions 1 and 2 are randomly selected in the sample). It is called method 1 in this letter. The full-time domain processing for each pixel cannot be ignored because the time delay is achieved by the moving stage. Therefore, the time consumed in taking the whole image is long (depending on the THz-TDS system, it can take hours to obtain an image with a hundred pixels)^[5,6]. For imaging with a higher resolution, more pixels are required, and the time spent becomes unacceptable. This situation becomes a strict limitation for the application of THz imaging.

In this work, a special data acquisition method was designed to reduce the time spent in collecting pixel information to achieve fast imaging. In the imaging process of this method (called method 2), the full-time THz pulse information of a single pixel should be first scanned as reference (position 1 line in Fig. 3). The maximum positive and negative peaks of the reference were acquired from the THz-TDS signal, e.g., points A and B shown in Fig. 3. Therefore, the corresponding time delay positions of these peaks were confirmed. At these two specific time delay positions, the corresponding THz pulse amplitudes for different sample positions were

obtained by moving the sample, such as points C and D in the position 2 line shown in Fig. 3. For the gray scale of each pixel, the amplitude difference between the two positions (i.e., A minus B or C minus D) was used as the linear reference. By analyzing all the differences (i.e., H1, H2, and so on), an image could be gained by setting the maximum as 255 gray degrees and the minimum as zero degree. Compared with method 1, method 2 achieved less movement in the time delay line. In the entire imaging process, the full-time THz pulse scan was performed only once, and only a short move was needed at the other sample positions. As a result, the total time spent was greatly shortened.

Experimental THz imaging of the same leaf sample using methods 1 and 2 is shown in Fig. 4. The resolution of the images is 25×25 pixels. In method 2, because the time delay positions are selected from the THz signal of the reference pixel, the difference between the different selections of the reference pixel should be confirmed. As two different reference pixels are randomly selected, the resulting images show less disparity with the others. Compared with that in method 1, the quality of THz imaging in method 2 is almost the same, with some of the images being even better. Furthermore, note that the time spent on the 625-pixel leaf image using method 1 is more than 1 h while less than 10 min using method 2.

Not only can method 2 be used in the transmission THz imaging system, but can be used in the reflection

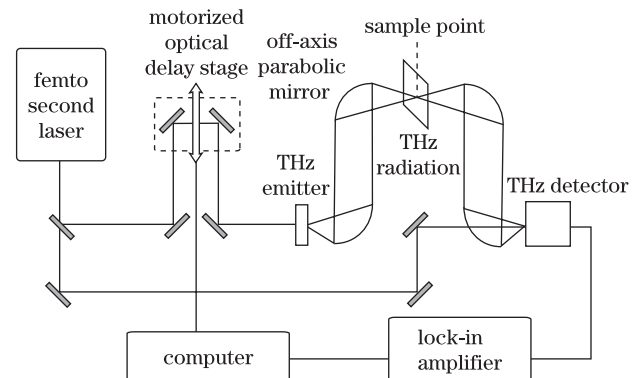


Fig. 1. Schematic of the imaging system based on THz-TDS.

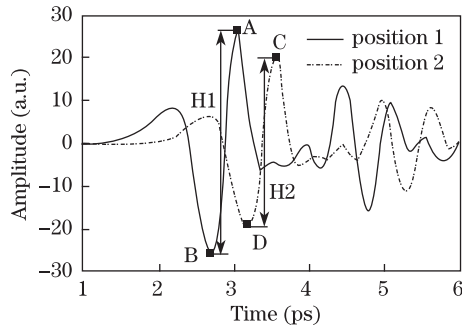


Fig. 2. Pixels' gray scale imaging solution using method 1.

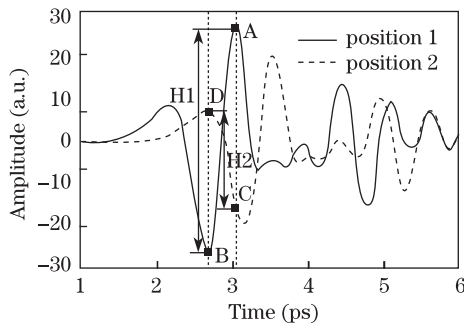


Fig. 3. Pixels' gray scale imaging solution using method 2.

system as well. Through analysis and comparison with method 1, method 2 shows the following characteristics: 1) more effective in time saving for large images with more pixels; 2) as the consequence of fast imaging, only use the amplitude information; 3) for the sample with less variation in thickness, imaging result shows less disparity between different reference pixels. However, when the sample thickness varies much, the imaging result becomes distinct by selecting the reference pixel. However, the preferable identification power of the image can still be obtained.

In conclusion, the reason for the long time spent in THz imaging is analyzed. A new imaging data acquisition method is designed to reduce the time cost. The

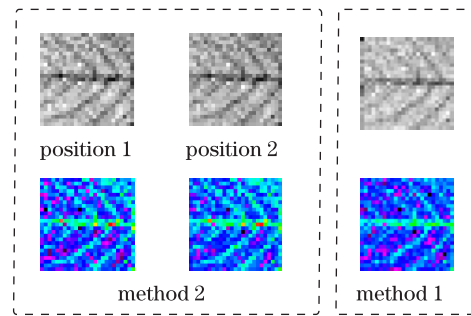


Fig. 4. Comparison of the images taken by the two methods.

experimental data confirm that this method is effective in its purpose. The characteristics of this method are also discussed.

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References

1. R. M. Woodward, B. E. Cole, V. P. Wallace, R. J. Pye, D. D. Arnone, E. H. Linfield, and M. Pepper, *Phy. Med. Biol.* **47**, 3853 (2002).
2. Q. Chen, Z. P. Jiang, G. X. Xu, and X.-C. Zhang, *Opt. Lett.* **25**, 1122 (2000).
3. B. Xue, W. H. Fan, J. Yang, H. L. Liu, and T. Y. Zhang, *Proc. SPIE* **7385**, 73851U-1 (2009).
4. B. Pradarutti, R. Müller, G. Matthäus, C. Brückner, S. Riehemann, G. Notni, S. Nolte, and A. Tünnermann, *Opt. Express* **15**, 17652 (2007).
5. K. Yang, G. Z. Zhao, and C. S. Liang, *Acta Opt. Sin. (in Chinese)* **29**, (Suppl.) 1-0102-05 (2009).
6. Y. Wang, Z. Zhao, Z. Chen, L. Zhang, and K. Kang, *Chin. Opt. Lett.* **7**, 690 (2009).