# Applications of Terahertz imaging

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*Abstract*: Within the last several years, the field of terahertz science and technology has changed dramatically. Many new advances in the applications of terahertz imaging have been developed. We present a pulsed terahertz real-time imaging with dynamic subtraction technique. The reflective image of a Nikon camera cap is obtained. The multiwavelength imaging and polarization imaging methods are also shown in the paper. At the end, we give the result of continous-wave (CW) standoff imaging with the imaging distance of 50m.

Keywords: THz, real-time imaging, THz phase imaging, standoff distance imaging

## 1. INTRODUCTION

Research has been carried out in THz region for several decades. Until now, the main drive came from applications of THz spectroscopy and imaging. Here, we carried out researches on the applications of pulsed and continuous THz imaging. In contrast with other frequency band EM radiation used in imaging modalities, we confirm that THz imaging technique has several advantages. For examples, THz imaging is quite efficient for homeland security, antiterrorism, nondestructive evaluation (NDE) biological applications.

For application of THz imaging, we have been explored several THz imaging techniques. For example, we have successfully carried out pulsed THz imaging for a hidden cap pistol through CCD real time imaging; We present a THz phase imaging method with multi-wavelengths; we present a method to measure the polarization state of pulsed THz wave by using a typical electro-optic sampling setup with <110> zinc-blende crystal as sensor. Standoff distance imaging is carrying out for some sample far from 50 m with continuous THz wave (CW THz) in our lab.

## 2. Real-time imaging with THz waves

We have presented an optoelectronic THz reflective imaging system with a real-time modality[1]. We are able to measure the two-dimensional electric-field distribution of THz wave without target movement.

The real-time imaging method can provide large bandwidth information. But the lock-in amplifier can't suppress noise dramatically with using the CCD camera, so we used the dynamic subtraction technique to reduce long-term optical background drift. We divide the synchronization frequency (1 kHz) by 32 and 64 by using a frequency divider. Then the two output frequencies are used to trigger optical chopper and CCD camera, respectively. When the camera captures two consecutive frames, one of them is with the THz beam blocked by the chopper and the other one is with the THz signal. Supposing the odd-number frame which contain the background signal is captured by camera, while the even-number frames contain the background only; then we can extract the signal dynamically, and the long-term background drift is greatly reduced. In addition, we can remove the short-term drift which cause by the laser well by subtracting the mean value of pixels at the edge of frame from the rest of image.

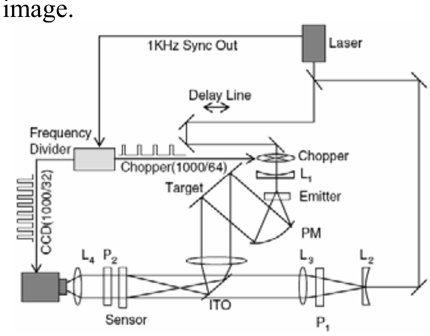


Fig. 1 Experimental setup of THz real-time imaging system with dynamic subtraction

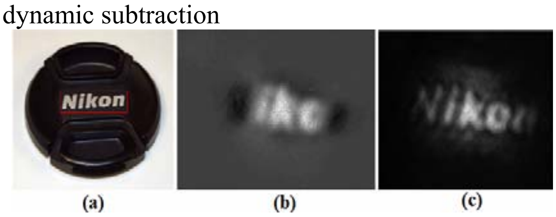


Fig. 2 Images of a lens cap: (a) optical image; (b) real-time THz image; (c) a false color image THz imaging

The experimental setup of the THz real-time reflective imaging system and THz reflective image corresponding to a Nikon camera's lens cap are shown in Fig. 1 and Fig. 2, respectively. The real-time image sows the electric field distribution on the sensor crystal at fixed time delay. The false color image is used the highest frequency region the reconstruct the THz image, it's very clear because we eliminate the phase mismatching pattern effectively by using another method.

## 3. Focal-plane multiwavelength phase imaging

We present a multiwavelength phase imaging method for THz reflective focal-plane imaging[2]. This novel approach can image object with larger optical length compared to using the largest wavelength in the THz spectrum and does not involve the usual phase unwrapping in the detection of phase discontinuity. Furthermore, this technique can effectively

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reduce background noise . But this method does not apply to the surface of absorptive materials.

Because the THz focal-plane image usually suffer from bad signal-to-noise ratio, the lock-in technology can't be adopted for these modalities. So we propose a multiwavelength phase imaging technique in the case of two-dimensional reflective imaging to reduce the noise significantly. This method not only renders a three-dimensional image, but also improves the ranging resolution to 300μm and allows one to resolve very fine details of the target, as shown in the Fig. 3. By the way, the experiment setup used here is same as the Fig. 1.

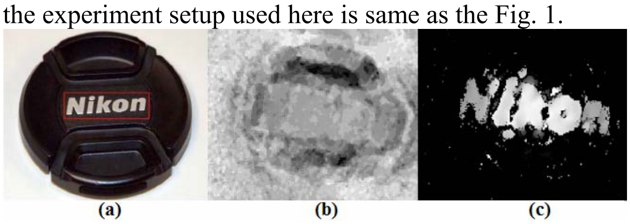


Fig. 3 Image of the lens cap: (a) optical image; (b) single-wavelength phase image; (c) multiwavelength phase image

## 4. Terahertz Polarization Imaging

Most THz imaging technologies have a common characteristic is that only one component of electric field vector is measured and the decrease in the amplitude of sample signal is usually interpreted as being caused by absorption and scattering. This make some imaging result can't be interpreted correctly. In fact, a rotation of the electric field vector induced by birefringence in the sample also can cause such a decrease. Besides birefringence, the polarization of a THz pulse can be changed by various other effects.

Here, we will introduce a polarization imaging method to improve the quality of THz imaging[3]. In the experiment, we make the polarization of the probe beam and the electric field of the terahertz wave in the same direction, and define the angle of their polarizations with respect to <001> axis of the ZnTe crystal is α. When α=0˚, the THz polarization is parallel to the <001> axis of ZnTe, the detected THz signal shows minor amplitude zero; whenα=90˚ the THz polarization is perpendicular to the <001> axis of ZnTe, the THz signal shows absolutely maximum amplitude. Since scattering and diffraction at the edge of the sample can cause the rotation of the THz polarization, the polarization infromation can be used to characterize an object with distinct edge features. The images of the object are shown in Fig. 4.

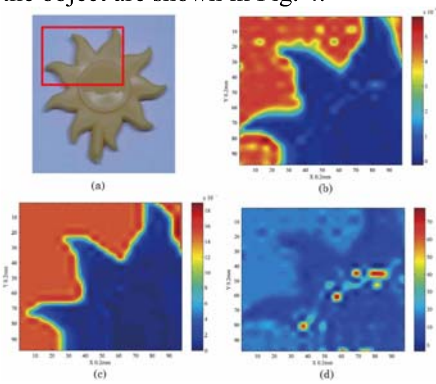


Fig. 4 Images of the sample: (a) optical image;only the protion in the rectangle is scanned; (b), (c)maximum value of the perpendicular and horizaontal components of the THz electric field in the time domain; (d) Angular rotation of the THz electric field

## 5. CW THz standoff distance imaging

We build a CW THz standoff imaging system at 0.2 THz. The system works at reflection geometry[4] and the imaging distance is 50m. A Gun oscillator is utilized as emitter an an unbiased Schottky diode operated at room temperature is employed as detector. A polyethylene fresnel lens is used to collimation THz wave for standoff propagation. Six aluminum mirrors are employed to increase distance. The sample is placed on an X-Y two-dimensional stage which is controlled by a computer. The collimated THz wave propagates in air and is focused to the sample by another polyethylene Fresnel lens. The back scatted THz wave from the sample surface is collected by the detector along the same path, the two-dimensional image of sample is obtained by a raster scanning fashion, and an air plane model is imaged at 50m from the imaging unit, which is shown in Fig. 5. The results show that this standoff imaging system has wide potential to be applied in the area inspection and screening.


Fig. 5 THz image result: (a) optical image;(b)standoff discatnce THz image

## 6. Conclusion

In numerous cases, laboratory feasibility tests of specific imaging applications have shown great promise, and in a few cases these have led to more realistic field tests. In order for the technology to gain more widespread acceptance, a great deal of research is needed. The terahertz field is likely to be a vibrant and active one for many years to come.

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