Terahertz Electric Field Imaging

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Terahertz (THz) imaging is attracting wide interest as a new generation of imaging system. THz waves have high transmittance in non-ionized media, and low energy which promises as application in non-destructive imaging. Using a large-gap photoconductive antenna biased with high voltage, well-de¯ned half-cycle THz pulses [1] can be generated. THz radiation has been widely used for time-domain spectroscopy by extracting both the amplitude and phase of the electric ¯eld from the Fourier transform of the temporal waveform. This technique can also be applied for two-dimensional imaging of a large object by translating the sample and measuring the electric ¯eld pixel by pixel [2]. The time required for such imaging, however, limits the application of such a technique in the real world. An alternative way of imaging is possible. Intense THz pulses from a large-aperture antenna can be used and an image obtained by mapping a time-resolved THz image into a time-resolved optical image using a pair of polarizers with a large-sized EO crystal in between. The optical image can be taken with a CCD camera. However, this mode of imaging gives the THz intensity, which is proportional to the ¯eld squared, instead of the electric ¯eld.

We have developed and demonstrated a new method of THz ¯eld imaging with the EO sampling based on the optical heterodyne detection, which enables electric ¯eld imaging. The detection setup is shown in Fig.1. The polarizer and the analyzer were ¯rst set to be crossed to each other and the quarter wave plate orientation was set be ¼=4 with respect to the polarizer. The analyzer was then rotated slightly to the optimal bias point [3], μ_b, which was 0.02 radian in our setup. Modulated intensity of horizontal polarized probe light from the EO crystal when the THz ¯eld was applied was detected by a CCD camera. The electric ¯eld induced birefringence contribution, μ, in the EO crystal is obtained as

$$\mu = -\mu_b + \sqrt{\mu_b^2 + I_s/I_0} \qquad (1)$$

where I_s is the probe intensity modulated by the THz electric ¯eld, and I_0 is the probe intensity.

In the experiment, a THz beam from a large-aperture photoconductive antenna projected a 45± oriented metal rod hidden in a dark paper box that was placed between the antenna and the TPX lens. Time-resolved and frequency-resolved images with and without the metal rod are shown in Fig.2.

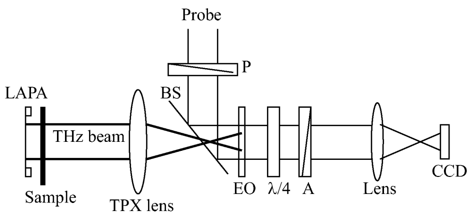

Fig. 1: Experimental setup for the THz ¯eld imaging. LAPA: a large-aperture photoconductive antenna, P: a polarizer, BS: a pellicle beam splitter, and A: an analyzer.

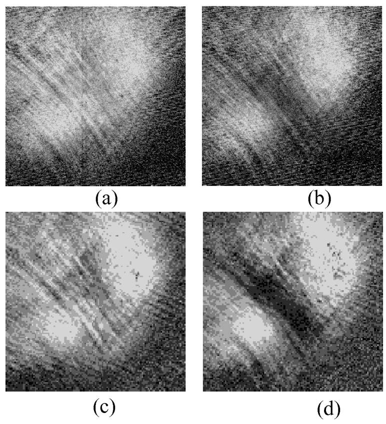

Fig. 2: The electric ¯eld image of (a) without and (b) with a 45± oriented metal rod in a dark paper box at a ¯xed time. The Fourier amplitude image at 0.82 THz (c) of the empty box and (d) with the rod are also shown.

The object is clearly identi¯ed from the image (b), which was taken at a time slightly after the peak time. The special feature of focusing broadband THz pulses causes the pale hole in the middle of the reference image [4]. Better resolution was obtained by Fourier transformed images at relatively high frequency as shown in Fig.2 (c) and (d).

In conclusion, THz electric ¯eld images were obtained by the EO sampling method with the EO crystal at a near zero optical transmission point. The time-resolved images can be applied to frequency-resolved THz imaging.

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