THz Field Imaging by Optical Heterodyne Detection Method

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A new field of imaging is opening up with the advent of terahertz (THz) electromagnetic field, at the regime between microwaves and light. With the success of THz time-domain spectroscopy in measurement of real and imaginary components response, real-time 2-D imaging with the both information is coming in use. While a crossed-polarizer geometry with expanded probe beam over the large-area of an electro-optic (EO) crystal and a CCD camera gives the intensity of THz, corresponding to squared electric field, phase-sensitive THz images are not obtained. Imaging of the field can be performed by applying the optical heterodyne detection method, where the optical field generated by the nonlinear optical process is heterodyne detected by a local oscillator that is a phase-shifted fraction of the probe light, to EO sampling. This method was first introduced by Jiang et al [1].

In detection by the optical heterodyne method, the configuration of crossed polarizers with the EO crystal and a quarter-wave plate having an axis parallel to the incident probe light placed between them is first set up. The analyzer is then rotated by angle, δ, so that the ratio of the difference of the intensities, when THz field is applied and is not applied, and the sum of the intensities becomes maximum. Phase difference, q, contributed by the EO effect of the probe light, which is proportional to the magnitude of the THz field can be expressed as

$$q = -d + \sqrt{d^2 + \frac{I - I_b}{I_0}},$$

where I and I_b are the intensities of the probe light transmitted through the above setup with and without applying THz field, respectively. I_0 is the incident probe intensity. The equation is valid for weak THz field, namely $q << 1$.

In this study, THz half-cycle electric pulses were generated by amplified pulses from a Ti:sapphire mode-locked femtosecond laser driving a biased large-aperture photoconductive antenna. A 18-mm-diameter THz beam projected a 3-mm metal rod concealed in a paper box. The image was obtained using a TPX lens and an EO crystal, as shown in Fig. 1. We found that the image of the interested object can be seen in the time window of large $|dE/dt|$ in the time-resolved images, and in frequency-resolved images after taking Fourier transformation to series of images.

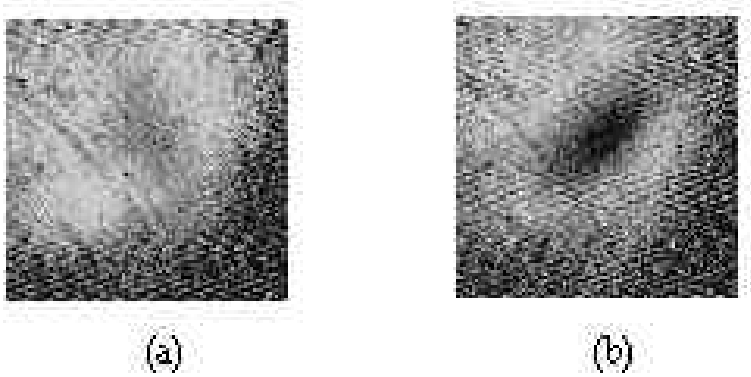

Fig. 1: Optical images mapped from THz field when the paper box (a) without and (b) with a 45-degree orientated metal rod was placed between the emitter and the lens.

[1] Z. Jiang, F. G. Sun, Q. Chen, and X.-C. Zhang, Appl. Phys, Lett. **74**, 1191 (1999).