Phase-Sensitive Fast Imaging of THz Radiation

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Imaging with terahertz (THz) radiation is attracting attention because of its potential applications in various field such as security check and product inspection. For real-world uses, the image acquisition time should be sufficiently short. By using high-peak-field THz radiation emitted from a large-aperture photo-conductive antenna, spatial scanning is not needed, and, fast (in principle, single-shot) THz imaging has been achieved [1]. Although, in principle, single-shot imaging is possible with this method, the disadvantage of this method is that not the field image but the intensity image is obtained since the conventional balanced detection is not applicable. In this study, we applied the optical heterodyne detection (OHD) technique to the fast THz imaging to enable phase-sensitive THz image acquisition.

In the experiments, a large-aperture GaAs antenna was pumped by femtosecond amplified Ti:sapphire laser pulses at a repetition rate of 1 kHz. The emitted THz pulses were focused by an off-axis parabolic mirror onto an EO (ZnTe) crystal. A probe pulse was split off from the pump beam, linearly polarized, and expanded to the size of the EO crystal. By placing a quarter-wave plate and a slightly off-axis polarization analyser, the light field generated by the EO effect in the ZnTe crystal was heterodyne detected with the original probe light field, which enables the phase-sensitive detection of the THz field. With the OHD method, we also obtained an S/N three times better than that obtained with the crossed polarizer configuration. Using an imaging lens, the spatial profiles of the THz field at the position of the EO crystal were obtained by a CCD camera.

In Fig. 1, an example of the images obtained is shown, which corresponds to the spatial profile of the focused THz field on the focal plane at the peak time. For each image, 30 shots of laser pulses were accumulated, which requires 30 ms. Figure 2 shows the temporal THz waveform at the central position reconstructed from images with the delay time scanned. This waveform shows good agreement with that obtained by the conventional balanced detection method.

By Fourier transforming the waveform at each position, the spatial profile of each frequency component was also obtained. The frequency dependence of the beam size obtained showed good agreement with those obtained with the Gaussian beam approximation.

[1] R. Rungsawang, K. Ohta, K. Tukamoto, and T. Hattori, J. Phys. D **36** 229 (2003).

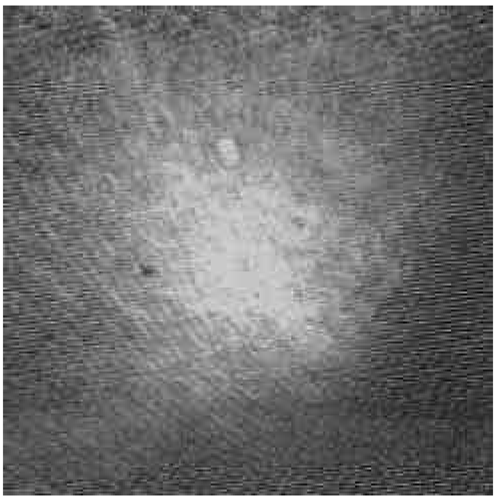

Fig. 1 A phase-sensitive THz image obtained using the heterodyne detection technique. This image shows the spatial distribution of the THz field on the focal plane. The accumulation time was 30 ms.

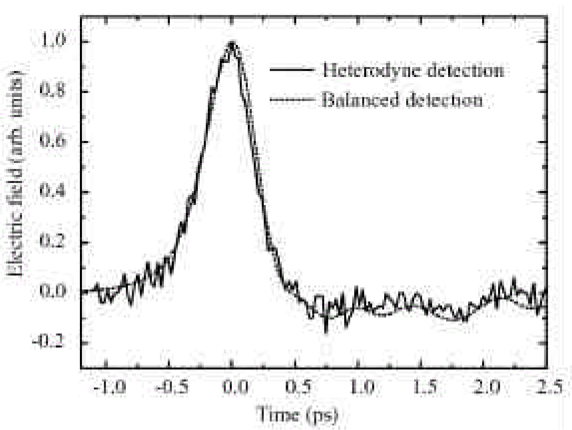

Fig. 2 The THz temporal waveform reconstructed from the phase-sensitive time-resolved images (solid line) and that obtained by the conventional balanced detection (dashed line).