Real-time One-dimensional Terahertz Time-Domain Spectroscopic Imaging for a Moving Object

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Terahertz (THz) spectroscopic imaging offers novel inspection modality to identify the chemical components of a given sample and to image the distribution of each chemical component on the basis of frequency-dependent absorption coefficient and/or refractive index [1, 2]. Despite the advantage of such the novel probing power, the conventional THz spectroscopic imaging has the disadvantage of low speed. In the case of THz time-domain spectroscopic imaging (THz-TDS imaging), it is necessary to proceed mechanical scanning for the sample position and the time delay between the THz pulse and the optical probe pulse. The resultant time consuming limits to the application to stationary objects. Considering the application to a monotonous moving object with a mechanical stage such as a belt conveyor, a real-time line (one-dimensional) imaging with THz-TDS (1D-THz-TDS imaging) is required to obtain two-dimensional (2D) THz-TDS image. Such real-time 1D-THz-TDS imaging can be achieved by a single-shot THz waveform measurement and 1D transverse imaging without scanning elements for the time delay and the sample position, namely a 2D spatiotemporal THz imaging. In this paper, we propose real-time 1D-THz-TDS imaging by combined use of the non-collinear free-space electro-optic sampling (FSEOS) [3] and a line focus of THz beam at a sample.

Figure 1 shows an experimental setup of real-time 1D-THz-TDS imaging. Intense THz pulse is radiated from a 4mm-thick <110> ZnTe crystal via optical rectification process of amplified femtosecond pulse light from a Spectra-Physics Hurricane laser, and collimated with a lens (L1, f = 50 mm). The first cylindrical lens (CL1, f = 50mm) gives line focusing of THz beam at the sample, and then the second cylindrical lens (CL2, f = 50mm) re-collimates the transmitted THz beam. Pair of the third cylindrical lens (CL3, f = 100 mm) and the fourth one (CL4, f = 100 mm) functions as imaging lens with respect to spatial axis and temporal axis in 2D spatiotemporal THz image, respectively. Then, the THz beam is incident to a 1-mm-thick <110> ZnTe crystal non-collinearly with a probe beam (dia. = 5 mm) at a crossed angle of 42°. The 2D spatiotemporal THz image is formed as spatial distribution of the probe beam in the ZnTe crystal, and then is imaged onto a 12-bit thermoelectric-cooling CCD camera (pco. Imaging Sensicam, 640*480 pixels, 10-fps frame rate) with a lens (L2, f = 150mm).

The resultant 2D spatiotemporal THz image without a sample is shown in Fig. 2(a), whose size is 19-mm by 15-ps. Figure 2 (b) shows temporal waveform of the THz electric field extracted from a single line (line a) along time axis in Fig. 2(a). One can confirm the THz electric field with 0.8-ps pulse duration. Fourier transform of 2D spatiotemporal image gives 2D spatiospectral image, namely 1D-THz-TDS image. Figure 3(a) and (b) show the 1D-THz-TDS images of amplitude and phase obtained from Fig. 2(a), respectively. Moderate single-to-noise ratio was resulted at the 1D-THz-TDS image of 19-mm by 1-THz.

In summary, we have demonstrated real-time 1D-THz-TDS image with size of 19-mm by 1-THz size by combined use of non-collinear FSEOS and a line focus of THz pulse at a sample.

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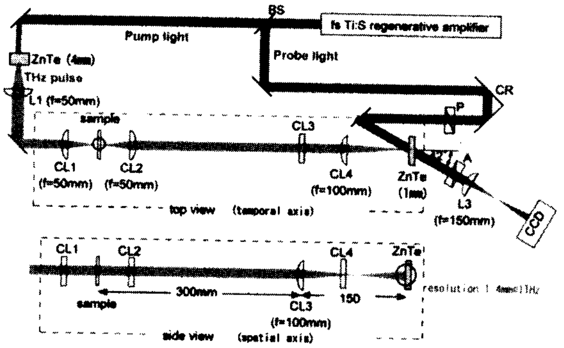
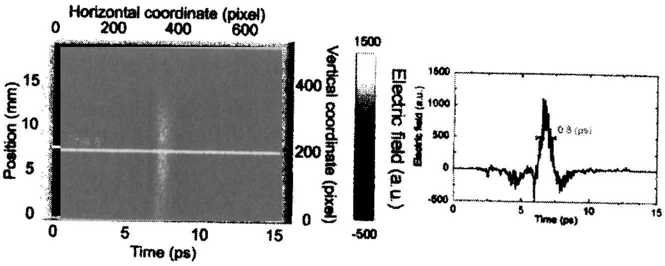
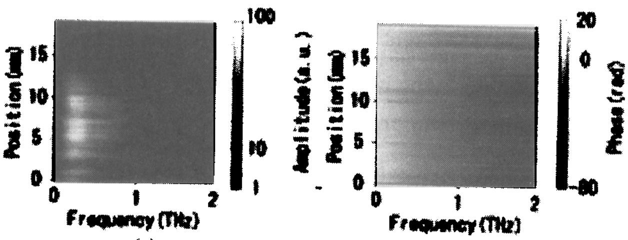


Fig. 1 Principle of 1D-THz-TDS imaging.



(a) (b)

Fig. 2 (a) 2D spatiotemporal THz image of 19-mm by 15-ps. (b) temporal waveform of the THz electric field extracted from a single line (line a).



(a) (b)

Fig. 3 1D-THz-TDS image of 19-mm by 2-THz. (a) Amplitude image and (b) phase image.

Reference

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