Ultrabroadband THz Wave Detection Using Photoconductive Antenna

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***Abstract*—We demonstrate ultrabroadband THz wave detection using a photoconductive antenna with a combination of an ultrashort pulsed laser with 5 fs pulse duration and a DAST crystal. We successfully detected an extremely wide frequency range from 0.5 to 170 THz.**

I. Introduction And Background

TIME-domain spectroscopy (TDS), which allows us to detect a waveform of electric field by using ultrashort laser pulses, is a powerful method for infrared spectroscopy and its broader bandwidth is highly desirable, because it provides us many advantages, e.g. simultaneous determination of real and imaginary parts of the dielectric function of materials [1]. There are two detection methods for the THz-TDS: electro-optic (EO) sampling and photoconductive (PC) antenna detection. The former utilizes phase distortion of ultrashort pulses by EO effect in a nonlinear optical crystal such as ZnTe or GaSe. Kübler *et al*. reported the EO sampling detection of ultrabroadband THz radiation beyond 120THz [2]. This method does not suit for the spectroscopy in the Restrahlen band due to optical phonons of the crystals (between 5 and 10 THz for typical nonlinear optical crystals). On the other hand, the PC antenna, which detects photocurrent induced by incident THz electric field gated with ultrashort pulses, shows smooth spectral response without blind regions, if the “reflection configuration” is adopted [3]. Recently we demonstrated ultrabroadband detection from 0.1 to 100 THz with one PC antenna using a combination of 10 fs pulses and a thin GaSe crystal and also suggested the high frequency limit can be extended to 130 THz with an advanced setup [4]. In the present experiment, we demonstrate ultra-high frequency detection with a PC antenna using a combination of ultrashort pulses with the duration of 5 fs and a DAST (4-dimethylamino-N-methyl-4-stilbazollium tosylate) crystal.

II. Results

For the generation of ultrabroadband infrared pulses, we utilized optical rectification by using a DAST crystal with a thickness of 0.4 mm. For the detection of the infrared field, we used a 30 µm long dipole-type antenna of gold with a 5 µm gap at the center, fabricated on a low-temperature grown GaAs substrate. We used a mode-locked Ti: Sapphire laser of which pulse duration is approximately 5 fs at a repetition rate of 80 MHz and center wavelength is 800 nm with an average power of 0.2 W for the generation and detection. The chirping of the laser pulses to the DAST crystal was controlled to obtain the broadest spectrum in near-infrared region.

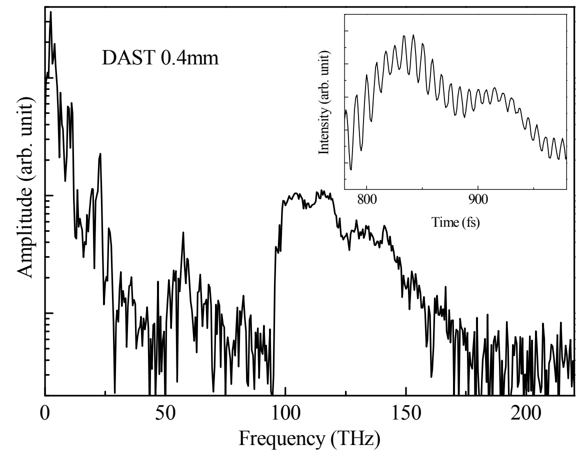

Fig. 1 An amplitude spectrum and a portion of a waveform (inset).

Figure 1 shows a Fourier transformed amplitude spectrum of an ultrabroadband THz wave generated with the DAST in logarithmic scale. A portion of a temporal profile extracted from the whole waveform is also shown in the inset right above. This ultrafast oscillation corresponds to the high frequency component above 100 THz in the main figure. The ultrabroadband spectrum from 0.5 THz, determined by the length of an optical delay line, to 170 THz was observed. The high frequency limit is determined by the absorption of a Ge filter, which is used to cut the tail of the laser spectrum down to 200 THz. On the other hand, the noisy structures in the lower frequency region below 100 THz are mainly caused by the absorption of phonons of the DAST.

In summary, we successfully observed an extremely wide frequency range from 0.5 to 170 THz with one PC antenna. This result opens a new way of ultrabroadband TDS in the whole infrared region.

References

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