Direct detection of the electric field in optical frequency region using photoconductive antenna

Masaaki Ashida
Graduate School of Engineering Science, Osaka University
PRESTO, Japan Science and Technology Agency

Time domain spectroscopy, which allows us to detect a waveform of electric field by using ultrashort laser pulses, is a powerful method for infrared spectroscopy, because it provides us many advantages, e.g. simultaneous determination of real and imaginary parts of the dielectric function of materials. However, its detection limit is usually several THz and much lower than that covered with a conventional FTIR. To push the limit to higher frequency, e.g. mid- or near-infrared region, we have used photoconductive (PC) antennas and ultrashort laser pulses. 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 [1]. Also, we applied this technique to solid state physics [2, 3].

In the present work, we achieved much higher frequency detection with a PC antenna using a combination of ultrashort pulses with the duration of 5 fs and a novel organic nonlinear optical crystal DAST (4-dimethylamino-N-methyl-4-stilbazollium tosylate). 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. Figure 1 shows a Fourier transformed amplitude spectrum of an ultrabroadband THz wave generated with the DAST in logarithmic scale [4]. 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 time domain spectroscopy in optical frequency region.

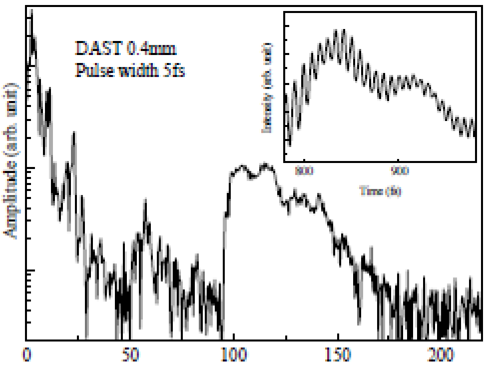

Fig. 1 An amplitude spectrum and a portion of a waveform (inset).

References
[1] M. Ashida, Jpn. J. Appl. Phys. **47**, 8221 (2008).
[2] I. Katayama, H. Shimosato, D. S. Rana, I. Kawayama, M. Tonouchi, and M. Ashida, Appl. Phys. Lett. **93**, 132903 (2008).
[3] I. Katayama, H. Shimosato, M. Ashida, I. Kawayama, M. Tonouchi, T. Itoh, J. Lumin. **128** 998 (2008).
[4] M. Ashida, R. Akai, H. Shimosato, I. Katayama, K. Miyamoto, and H. Ito, *Ultrafast Phenomena XVI* (Springer Series in Chemical Physics, 2009), in press.

Masaaki Ashida
Associate Professor, Dr.
Department of Materials Engineering Science, Graduate School of Engineering Science, Osaka University. 1-3 Machikaneyamacho, Toyonaka, Osaka, Japan
PRESTO, JST, 4-1-8 Honcho, Kawaguchi, Saitama, Japan
Phone/Fax: +81-6-6850-6507, E-mail: ashida@mp.es.osaka-u.ac.jp