Real-time terahertz time-domain spectroscopy based on asynchronous optical sampling

K. Moon, Y. Han, E. Jung, M. Lim, C. Im, and H. Han
POSTECH, Pohang, Gyeongbuk 790-784 , Korea

***Abstract*— A real-time terahertz time-domain spectroscopy (THz-TDS) system based on the ASOPS technique was demonstrated. The THz TDS system had a maximum time delay of 10 ns, corresponding to a 3 m-long time delay, and a maximum frequency resolution of 100 MHz. For single-scanning measurements, we demonstrated real-time THz measurements in both time and frequency domains. The typical signal-to-noise ratio (SNR) was better than 60 ~ 70 dB within 50 s.**

I. Introduction and Background

THz-TDS system has been a powerful tool in the study of numerous field of science and technology. The conventional THz-TDS system relies on a sampling technique, in which pump-pulses are used to generate THz pulses, while time-delayed probe pulses are used to detect THz pulses. With a mechanical, it usually takes more than several minutes to get a single scan. In order to reduce the data acquisition time, there have been several techniques including a rotary optical delay line [1] or a galvanometer-based oscillating optical delay line [2]. By using the rotary optical delay line, a high-speed THz-TDS system up to 400 Hz of acquisition rate with maximum time delay of 500 ps was demonstrated. However, implementing high-speed THz-TDS with a time delay more than 1 ns is practically impossible with such a mechanical delay line.

Recently, a THz-TDS system based on asynchronous optical sampling (ASOPS) was demonstrated [3-4]. In the ASOPS technique, two femtosecond lasers are operated with a small difference frequency. They provide two laser pulse trains whose time delays are automatically scanned without any mechanical delay line. Therefore, ASOPS can be employed to eliminate the mechanical delay line from the THz-TDS system. In the ASOPS system, the maximum time delay is the inverse of the repetition rate of the fs-laser. With a 100 MHz repetition rate, 10 ns time delay can be obtained.

In this work, we present a real-time THz-TDS system employing the ASOPS technique with a 10 ns time delay. We measured THz absorption lines of water vapor, and transmission spectra of THz- supermirrors with THz transients longer than 4 ns.

II. Results

The high-speed THz-TDS system based on the ASOPS technique consisted of two 10-fs mode-locked Ti:Sapphire lasers (Femtolasers). One was used for the pump pulse and the other for the probe pulse. The fifth harmonic of the repetition rate of each fs-laser was synchronized to an external RF generator. A phase-locking system (Femtolasers) was used to synchronize the repetition rate. The measured timing jitters of the two lasers were less than 60 fs. InAs wafers and photoconductive antennas were used to generate and detect THz pulses. The repetition rate of the pump laser (f) was set to100 MHz, and the frequency difference between two lasers (Δf) was 20 Hz. The signal-to noise ratio (SNR) was 30 ~ 40 dB for real-time single data acquisition. The typical signal-to-noise ratio (SNR) better than 60 ~ 70 dB was obtained by averaging 1000 single-scan data within 50 s.

Figure 1 shows the absorption spectrum of water vapor. The measured absorption lines are in good agreement with previous results [5]. We also measured the transmittance spectrum of a THz supermirror. Since the THz supermirror has distributed-reflection structures, the transmitted pulse is expected to show a long transient up to several nanoseconds. Therefore, it is almost impossible to fully measure the transmitted pulse with conventional TDS system using a mechanical delay line. However, with our ASOP-based THz TDS system it was possible to fully measure such a long transient within a few tens of seconds. As shown in Fig. 2, a THz transient longer than 4 ns was successfully measured.

III. Conclusion

We have demonstrated high-speed ASOPS-based THz-TDS with a maximum time delay of 10 ns. The transmission spectra of water vapor and of a THz supermirror with a THz transient longer than 4 ns were measured. The typical signal-to-noise ratio (SNR) was better than 60 ~ 70 dB within a data acquisition time of 50 s.

References

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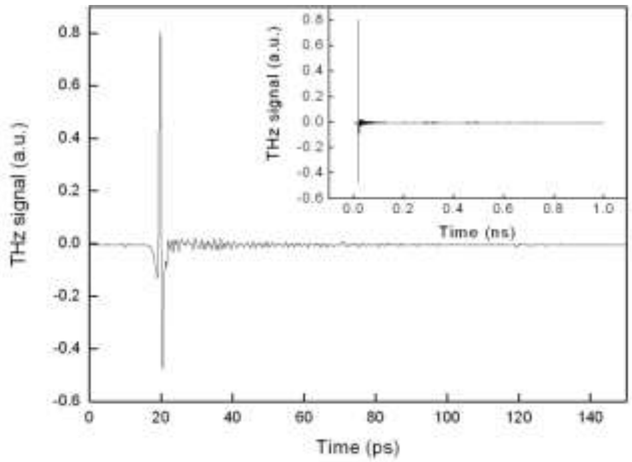

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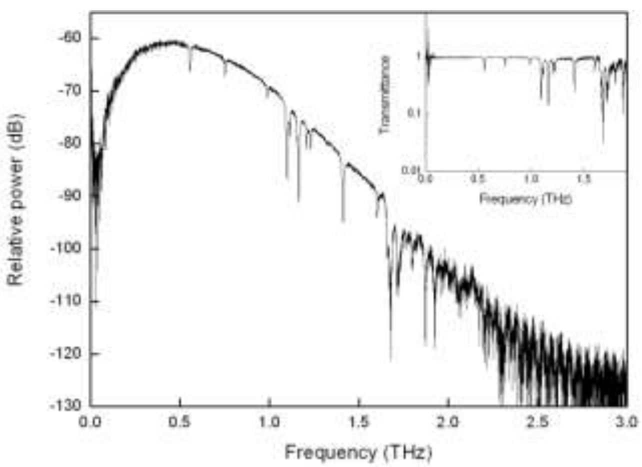
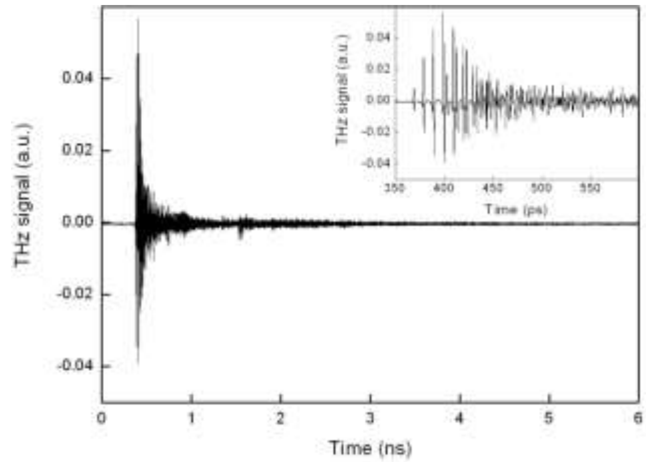


b)

Fig. 1. a) THz signal measured in atmosphere with an acquisition time of 50 s, and b) transmission spectra.



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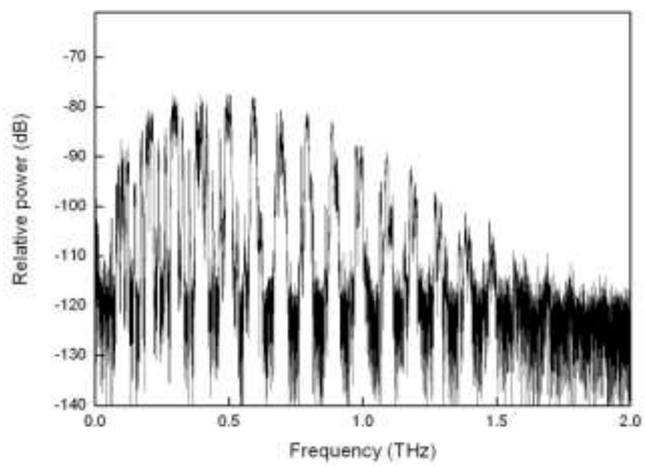

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Fig. 2. a) THz signal after transmitted through a THz supermirror, and b) spectrum of transmitted THz pulse.