Non-destructive inspection of chemicals in mail envelopes using an injection-seeded terahertz-wave parametric generator

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***Abstract*— The injection-seeded terahertz parametric generator (is-TPG) is suitable for the non-destructive inspection of illicit drugs and explosives concealed in mail because of its high power generation and sensitive detectors. This study examined a terahertz (THz) spectrometry method suitable for the non-destructive detection of chemicals concealed in mail envelopes. We compared the transmission spectra of three saccharides in different covering materials using is-TPG and terahertz time-domain spectroscopy (THz-TDS).**

I. INTRODUCTION

IN recent years, there have been numerous attempts to smuggle illegal narcotics by concealing them in international mail. Combatting this requires a non-destructive technique that can identify such illegal substances in mail. Terahertz (THz) waves can pass through a wide variety of materials, and many chemicals show specific frequency-dependent absorption in the THz range. Therefore, it is logical to consider non-destructive mail inspection techniques that use THz waves. Terahertz time-domain spectroscopy (THz-TDS) is a standard method for detecting THz signals that collects the transmitted or reflected THz pulse using photoconductive antennae with a gap of several micrometers. When mail is inspected using this technique, the small detection area presents problems for making spectroscopic measurements because THz pulses are refracted, diffracted, and scattered by the surrounding envelope or packing material. By contrast, an injection-seeded terahertz parametric generator (is-TPG) is monochromatic with a tunable THz wave source and can obtain THz spectra directly over a relatively wide detection area. Therefore, the spectra from the contents contained in covering materials that refract, diffract, or scatter THz waves can be measured using is-TPG. Previous research showed that THz parametric oscillators that are tuned to THz wave frequencies can detect illicit drugs [1]. Recent is-TPG research has resulted in a significant increase in power output and the highly sensitive detection of THz-waves [2, 3]. Studies have also developed a high dynamic range spectrometer using an is-TPG [4]. According to the literature, an is-TPG is thought to be more effective for the detection of illicit drugs concealed in mail than THz-TDS. In this study, in order to evaluate the performance of is-TPG in mail inspection, we measured the transmission spectra of various chemicals in different covering materials (simulating illicit drugs concealed in mail) using an is-TPG spectrometer, and compared the spectra with those measured using THz-TDS.

II. EXPERIMENTS AND RESULTS

Fig. 1 shows the experimental setup of the is-TPG transmission spectroscopy. The frequency band of this system was from 1.1 THz to 2.5 THz and this system had the dynamic range of 70 dB at the center frequency, as shown in Fig. 2.

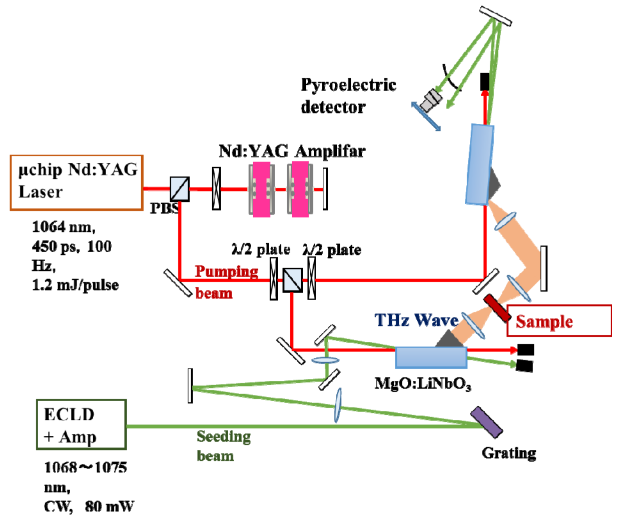

Fig. 1. The is-TPG transmission spectroscopic system

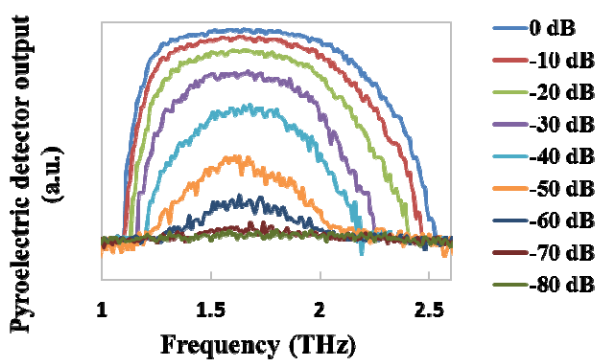

Fig. 2. The spectra of is-PTG

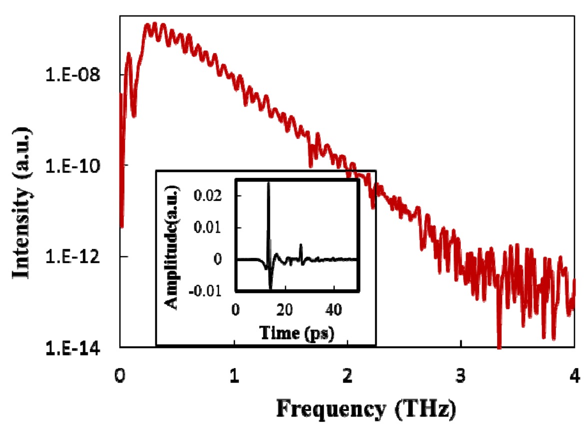

Fig. 3. The pectrum of THz-TDS

Fig. 3 shows the spectrum and the temporal waveform of the THz-TDS transmission spectroscopic system arranged for comparing the transmission spectra of chemicals in covering materials to those of measured by the is-TPG. To prevent the unnecessary attenuation due to the water vapor absorption of the terahertz waves, the transmission measurements by both the is-TPG and THz-TDS were performed under a nitrogen gas atmosphere.

The samples used in this study were shaped to appear as illicit drugs concealed in international mail. To this end, we enclosed three powdered saccharides—maltose, glucose, and fructose—in plastic bags that were approximately 0.5 mm thick, including the powder. Then, the bags were placed in paper and bubble wrap envelopes. Each saccharide has several absorption peaks from 1.0 to 2.5 THz, with maltose showing characteristic absorption at 1.2, 1.6, and 2.0 THz, glucose at 1.4 and 2.1 THz, and fructose at 1.7 and 2.1 THz. Fig. 4 shows the transmission spectrum of each sample measured using is-TPG and THz-TDS. Using is-TPG, all of the absorption peaks except for the maltose absorption peak at 1.2 THz could be identified clearly. By contrast, using THz-TDS, the absorption peaks below 1.6 THz for each sample could be identified, while the absorption peaks at higher frequencies could not be distinguished from background noise. Similar results were seen using covering material with a complex shape, such as corrugated cardboard. These results demonstrated that is-TPG spectroscopy was effective at identifying chemical compounds within covering substances, i.e., in detecting illicit drugs concealed in mail.

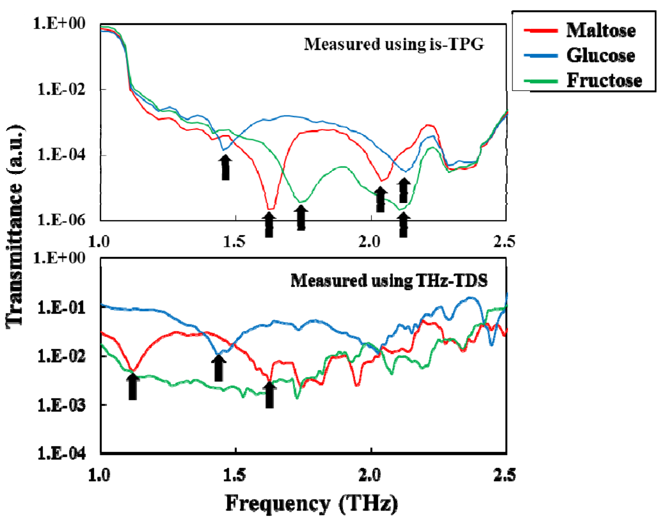

Fig. 4. Transmission spectra of powdered saccharides in standard bubble wrap envelops.

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