Application of ARP's terahertz spectrometer with exemplary data

The border security is facing a challenge of detecting narcotics dissolved in gasoline or diesel, a smart technique used by the smugglers. ARP's terahertz technology can be used to discern between pure and contaminated gasoline. It has other important applications as well. This document summarizes experimental data of (1) detection of impurities in gasoline, (2) real-time, online process monitoring, (3) molecular identification, (4) label-free DNA hybridization analysis, and (5) parts per trillion (femto-molar) sensing; thus demonstrating functionality of the technology. The technology can be applied for remote detection of explosives and other controlled substances.

1. Detecting contamination in gasoline by TeraSpectra

Presence of very small amount of contaminant in fuel (e.g., gasoline, diesel, etc.) can be conveniently determined by terahertz measurements. As an example, detection of chromium salt in regular gasoline was attempted. Cr (III) Acetate Hydroxide $[(CH_3CO_2)_7\,Cr_3\,(OH)_2]$ (CrAH) was dissolved in gasoline at 1.9105 mg/ml. Time resolved spectra of gasoline and CrAH solution were acquired. Fig. 1 shows the normalized spectra of both samples. It is seen that gasoline alone has a higher transmission compared to CrAH solution. Fig. 2 shows the Fourier transform frequency spectra corresponding to the time-resolved spectra of Fig. 1. There are significant differences between the respective spectrums that can be exploited for discerning the contaminated gasoline from the uncontaminated one (see Fig. 3). This technique can also be used for remote detection of explosives.

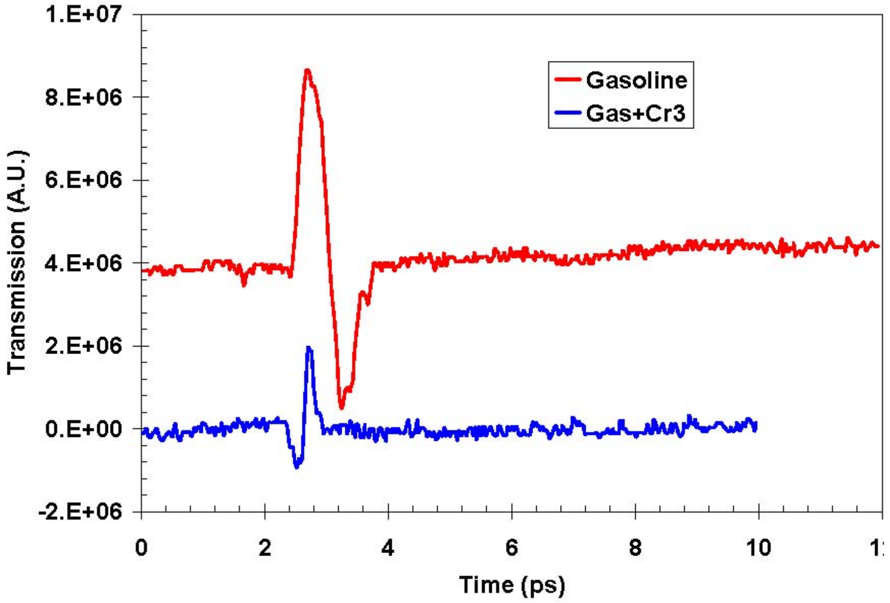

Fig. 1. Normalized time-resolved spectra of gasoline (red) and Cr (III) Acetate Hydroxide $[(CH_3CO_2)_7\,Cr_3\,(OH)_2]$ solution in gasoline at 1.91 mg/ml (blue). Presence of salt in gasoline reduces the transmission of THz power through the sample.

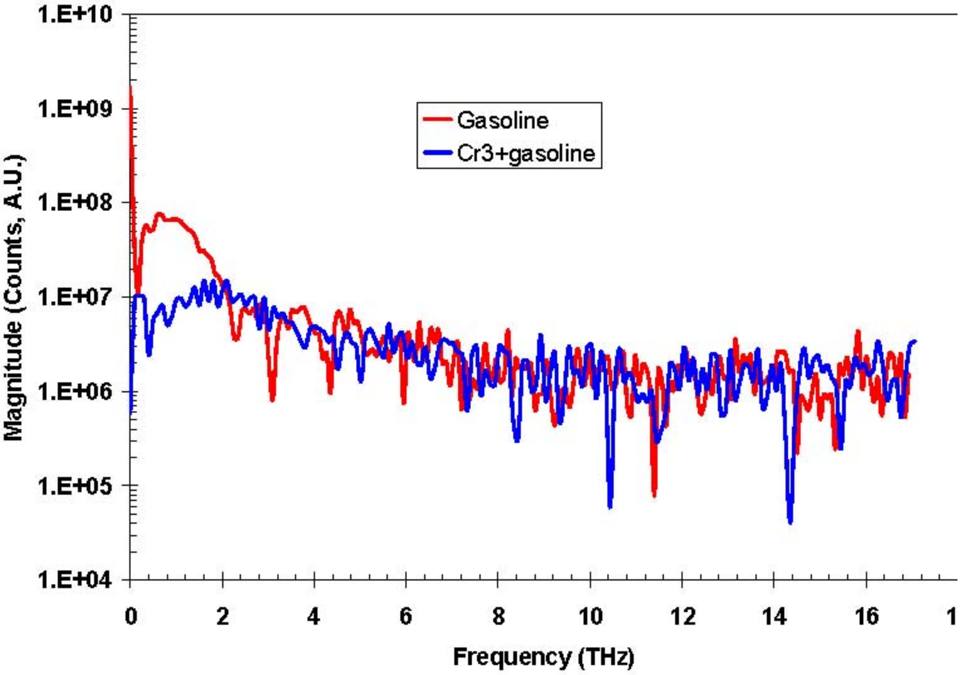

Fig. 2. Fourier spectra of gasoline (red) and 1.91 mg/ml CrAH solution (blue) corresponding to the time-resolved spectra of Fig. 1. The spectra are clearly different allowing differentiating between the two samples. (Cuvette effect, if any, was not subtracted).

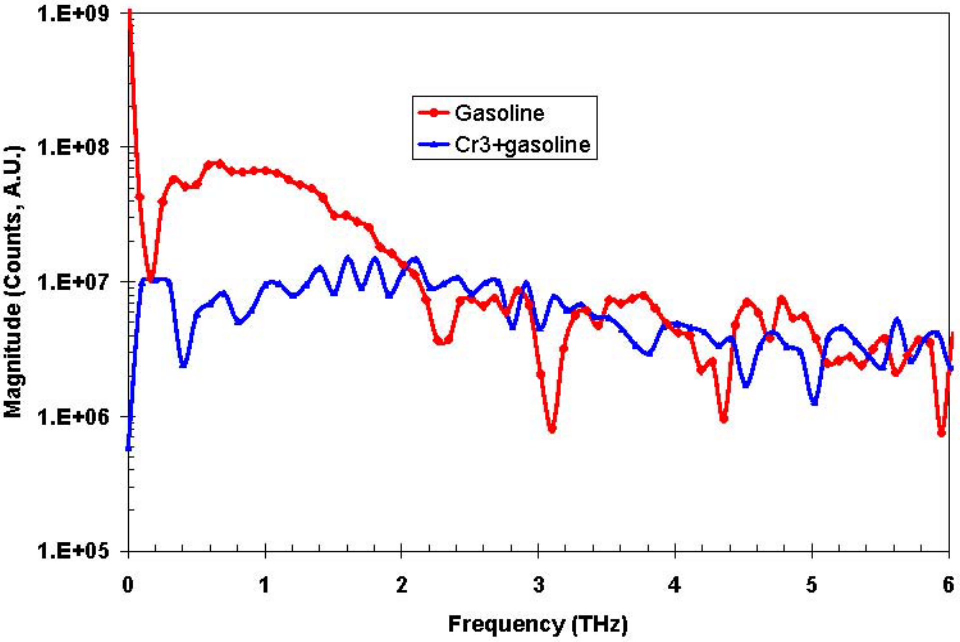

Fig. 3. Close-up of spectra in Fig. 2. An interesting observation is that at low frequencies below ~2.25 THz gasoline (red) exhibit higher transmission than CrAH solution (blue). However, at higher frequencies (above ~2.25 THz) gasoline exhibits a few absorption peaks that are not present in the CrAH. Thus the frequency dependent behavior of the two specimens reveals some interesting molecular interaction between the CrAH and gasoline that can not be fully understood from the present data.

2. **Real-time, online process monitoring example**

TeraSpectra© is a high sensitivity machine with sensitivity level as low as parts per trillion. It also has a real-time response to variations in process variables. Once calibrated, process variables can be monitored with high precision. Additionally, by monitoring the terahertz signature spectra of selected molecules, their presence or absence can be determined online basis. Fig. 4 shows a conceptual setup for process monitoring. When a perturbation is presence in a target process variable, the spectrometer can detect that in real time, as shown by the fluctuations in counts (Fig. 5). The spectrometer goes back to the steady state in the absence of external perturbation as indicated by the straight lines.

Fig. 4. Example of process monitoring with TeraSpectra.

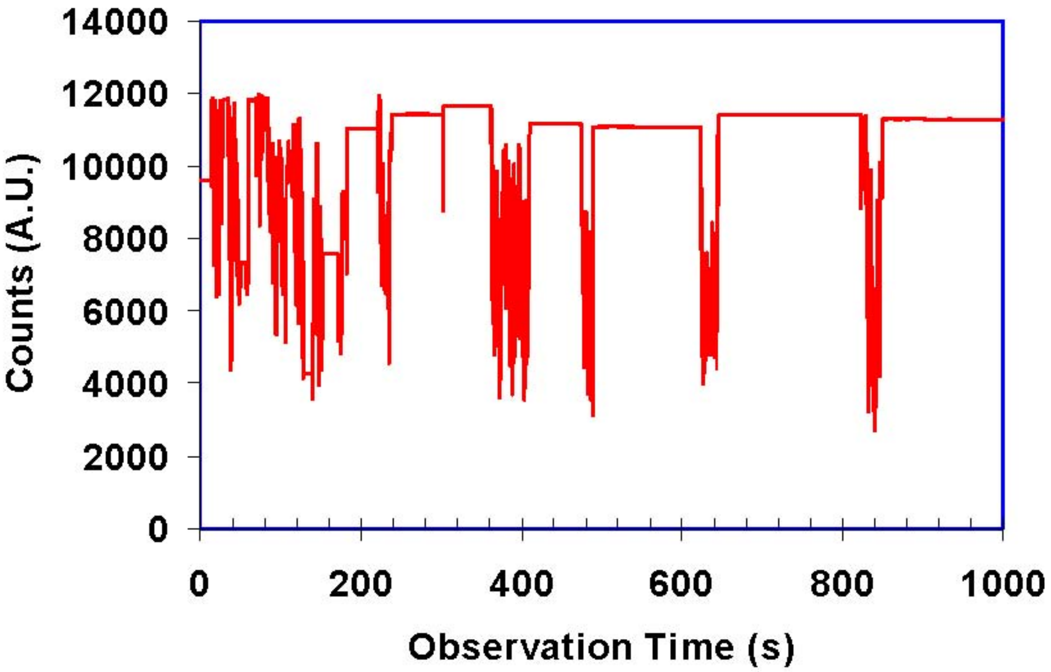

Fig. 5. Real-time response of the spectrometer as a function of external process fluctuation (simulated). When a perturbation is presence, the spectrometer can detect that in real time, as shown by the fluctuations in counts. The spectrometer goes back to the steady state in the absence of external perturbation as indicated by the straight lines.

3. **Molecular Identification**

Terahertz interaction with a given molecule results in unique spectral signature. Fig. 6 shows Fourier spectra of stratum corneum (control) and the same sample treated with an active species. The treated specimen shows characteristic peaks of the active ingredient while the untreated specimen shows a monotonic behavior. Thus TeraSpectra can be used to establish molecular signature.

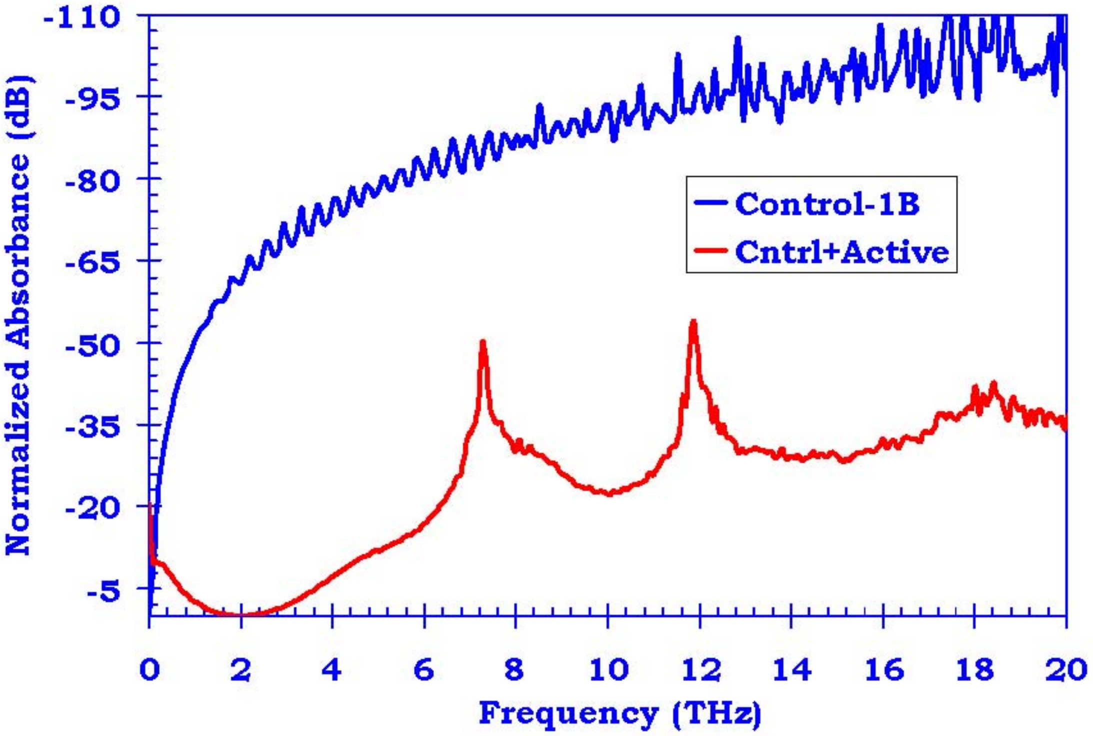

Fig. 6. Spectral signature of stratum corneum (control, blue line) and the control treated with an active ingredient (red). Terahertz can clearly detect the presence of an active as evidenced from the spectra. Samples complement of Professor Bozena Michniak-Kohn of Rutgers University, NJ.

4. **Label-free DNA hybridization analysis**

Terahertz technology allows straightforward detection of DNA binding state (i.e., discriminating between single stranded and double stranded DNA fragments) without labeling. An example of 25-mer oligonucleotide is shown below.

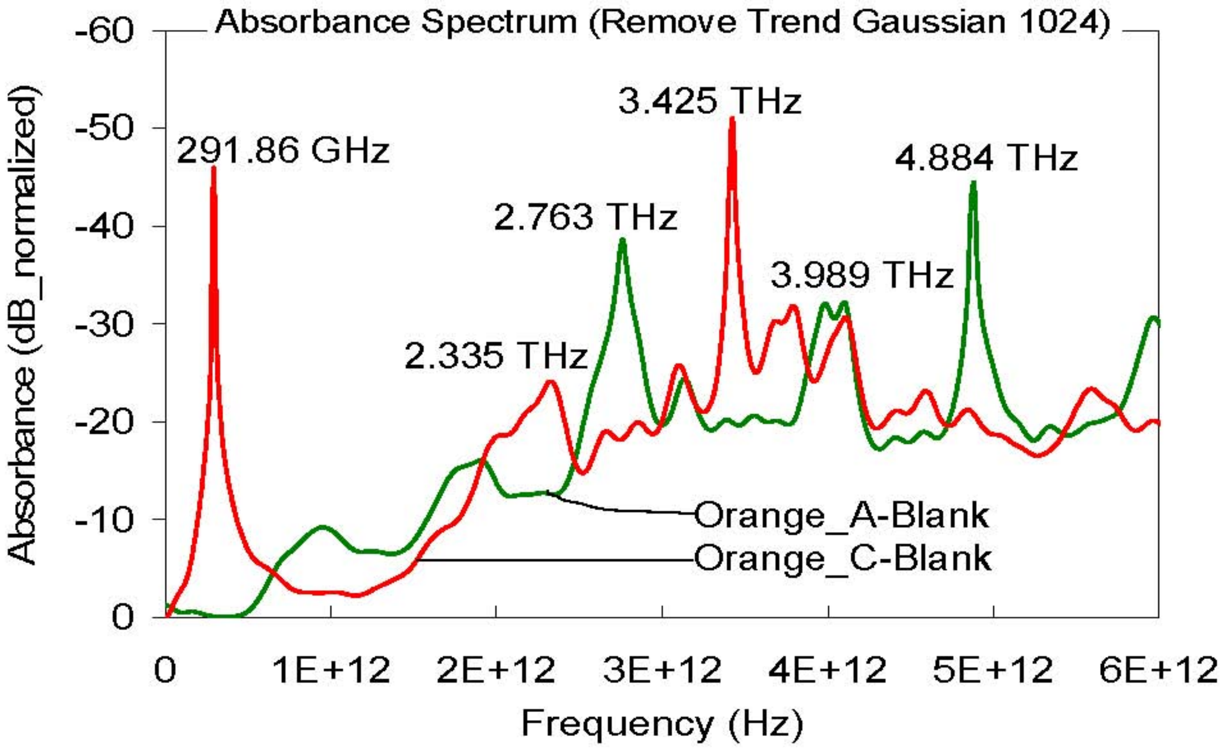

Fig. 7. Absorbance spectra of single-stranded (Green) and double-stranded (Red) (hybridized) DNA. Characteristic peaks allow distinguishing between the hybridization states. Samples complement of Dr. Bruce Stanley of Penn State University College of Medicine, Hershey, PA.

5. Parts per trillion (Femto-molar) sensing

Another application is in trace analysis. Parts per trillion levels can be sensed in liquid or gaseous of environment. Two examples are presented below. Fig. 8 exhibits data of methanolic solution of an organic compound (Ceraphyl) used in personal care products. Fig. 9 shows data of Cr(III) salt in water.

6. Contact

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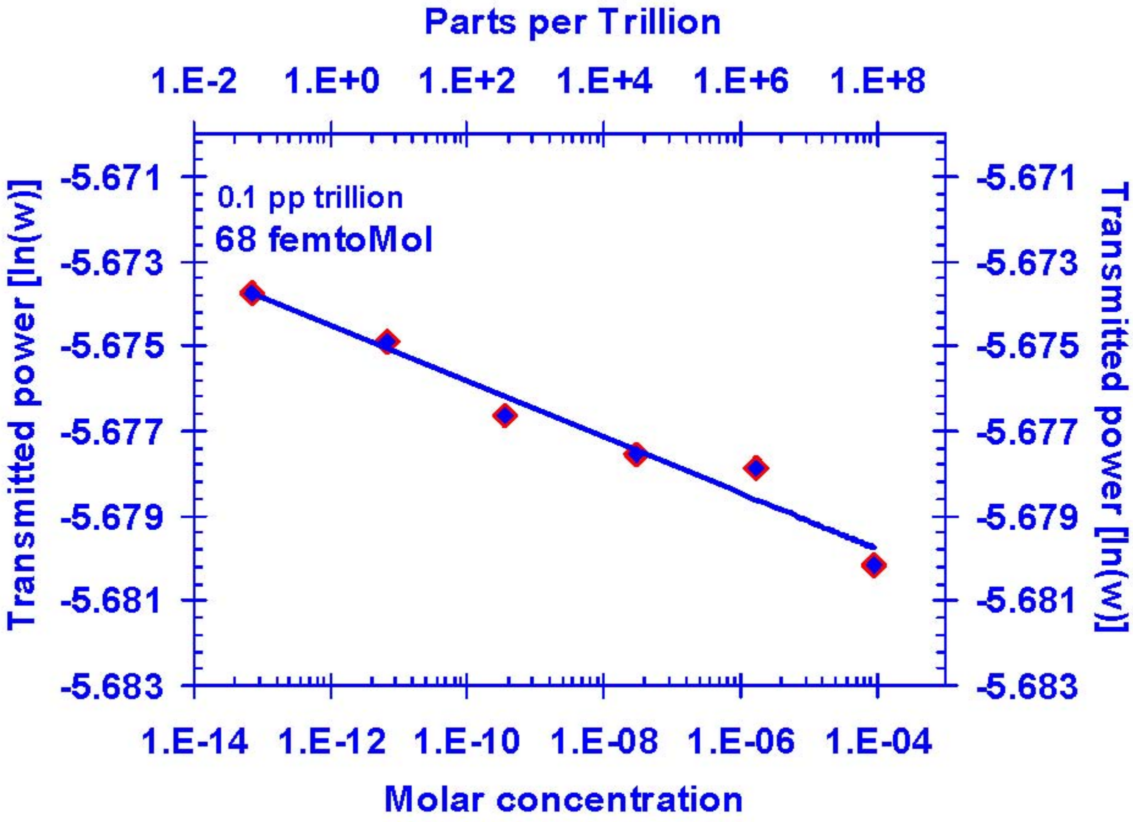

Fig. 8. Sensing an organic compound (Ceraphyl) at parts per trillion (or femtomolar) concentration from an organic solution (methanol).

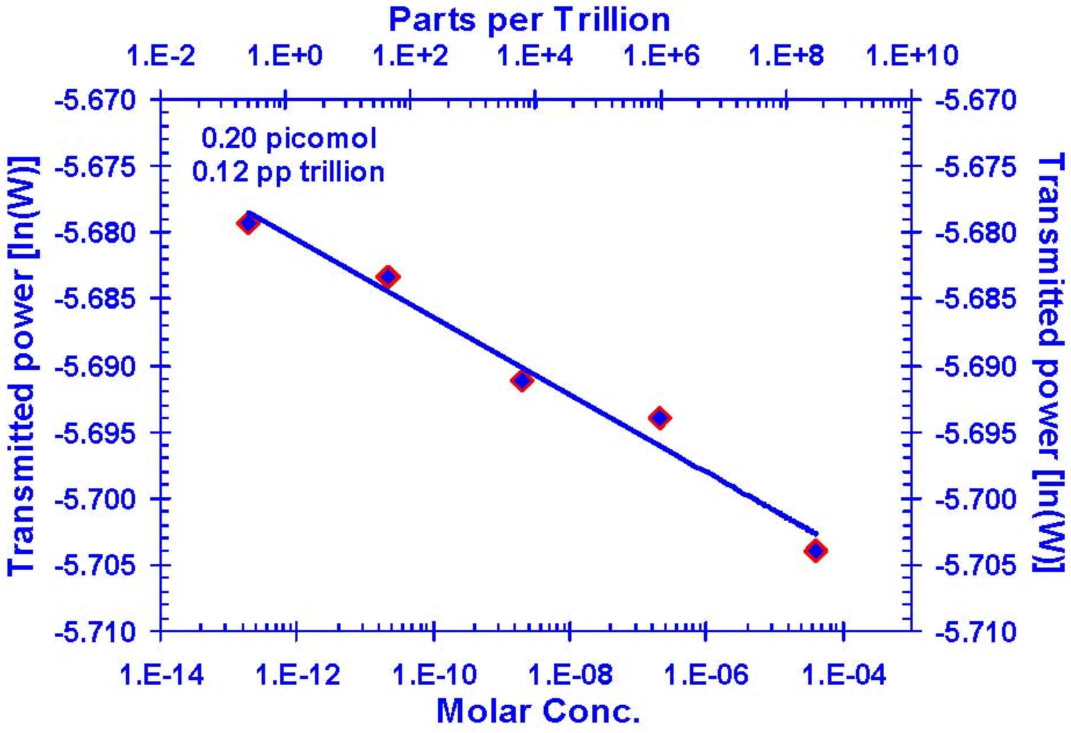

Fig. 9. Detecting parts per trillion of an inorganic salt (Cr^{3+} Acetate Hydroxide) from aqueous solution.