**Electronic Terahertz Spectroscopic Imaging of Explosives and Weapons**

**Abstract:**

We seek to build imaging arrays for screening personnel through portals using new microwave circuits that produce coherent signals for electronic terahertz (THz) generation and detection integrated circuits. Since we have demonstrated that these circuits can distinguish reflection signatures of a variety of threats from those of clothing and skin, they can be used for screening human subjects working in conjunction with established metal screening portals, which will provide a completely new measure of threat imaging and hence security.

We developed a broadband electronic THz system capable of reflection and transmission spectroscopy of materials. We also developed broadband antennas with nearly 20 dB of gain that can be integrated with such THz systems.
Objectives
The objectives of this work were to advance the state of electronic pulsed terahertz systems to broadband
dielectric reflection measurements of important energetic materials and plastic weapons in the 1–1000 GHz
regime using integrated-circuit nonlinear transmission lines and antennas as generators of this radiation.
Previous work from our lab had already demonstrated spectral signatures from a variety of threats, including
bacterial spores of various strains[1-5].

Status of effort
The project is completed.

Accomplishments/New Findings
We built several pulsed THz spectroscopy systems using GaAs nonlinear transmission lines (Figure 1), and we
conducted and published data from transmission and reflection experiments on a variety of materials, including
biological materials, such as anthrax simulates (bacillus cereus [B. cereus], B. globigii, and B. thurengiensis),
both wild-type and mutant strains (Figure 2) [1-5]. We obtained sample collection and particle concentration
technology from MicroEnergy Technologies, Vancouver WA, for some of this work.

We also focused on reducing the cost of our technology by developing circuits that promote integrating the
coherent oscillators and amplifiers needed to drive the pulsing circuitry. This will open the door to eventual
integration of our technology into familiar metal-detection portals, which we consider a major potential
advantage of our approach over that of other screening technologies.

An extremely important factor in advancing spectroscopic imaging is the ability to suppress standing-wave
phenomena. With a startup company, Tera-X, we developed modulation techniques to minimize the effects of
standing waves in broadband THz spectra, and also developed manufacturable ultrawideband (UWB) antennas
that exhibit nearly 20 dB of gain and can be scaled to the THz regime. Broadband sensing and spectroscopic
imaging using both reflection and transmission in the 1-1000 GHz regime can be done with pulsed terahertz
(THz) circuits, such as nonlinear transmission lines (NLTLs)[6-10]. Yet some of the most significant limitations
of any time-domain THz system—whether purely electronic or optoelectronic—arise from the lack of
amplifiers, whether power or low-noise. To address this pressing need, we develop ultrawideband antennas that
have greater gain and better polarization characteristics than the planar antennas used in today’s THz systems.
Many concepts imported from lower-frequency UWB systems are valid for the THz regime, as well.

We take two approaches to these coherent measurements: (1) using a conventional source/detector arrangement
with sampling detectors or (2) spatially combining the freely propagating beams from two matched picosecond
pulse generators. The latter method employs a dual-source interferometer (DSI) modulating each harmonic of
one source with a precisely-offset harmonic from the other source—both sources being driven with stable
phase-locked synthesizers—the resultant beat frequency can be low enough for detection by a standard
bolometer. Room-temperature detection possibilities for the DSI include antenna-coupled Schottky diodes.

This year, using the reflection configuration, we have measured absorption characteristics of a variety of targets,
including bacillus spores collected on optical micropillars (from MicroEnergy Technologies, Vancouver WA),
which serve as concentrators. Thus, applying THz electronic systems as broadband, standoff sensors will be
enabled by the benefits gained from new antennas and optical arrangements.
Off-axis paraboloidal mirrors

Generating Antenna

sample

Detecting Antenna

Figure 1. Reflection setup for measuring absorption of bacterial spore samples.

B. cereus (BC) 85
B. globigii (BG) 76
B. thurengiensis (BT) 33

Figure 2. Picture of sample holder and list of bacterial spores measured with the sample masses in mg.

Figure 3. Results of broadband reflection measurements from samples detailed in Fig. 2. Ten trials were conducted on each sample; the error bars show +/- one standard deviation. Note that distinguishability of samples increases at higher frequencies.

We conducted several reflection measurements of bacterial spore samples, first using 33-85 mg masses on a highly-reflective mirrored surface (Figures 2-3), then using < 10 μg masses on optical micropillars (Figures 4-5). We note that in both cases, we could distinguish among the variety of spores when using a broadband reflection technique, though with three orders of magnitude reduction in sample mass, the limits of distinction were being reached (Figure 5).
Figure 4. Micropillar array mounted on glass slide (inset: close-up of array), with list of bacterial spore types and mass in µg.

![Micropillar array](image_url)

**Note:** The array includes control, BG, BT, and BC samples.

Figure 5. Results of broadband reflection measurements from samples detailed in Fig. 4. Ten trials were conducted on each sample; the error bars show +/- one standard deviation. Note that distinguishability of samples is less than that possible with greater sample masses (Figure 3).

**Personnel supported**

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**Publications**

(a) Manuscripts submitted, but not published

(NONE)

(b) Papers published in peer-reviewed journals


(b) Papers published in non-peer-reviewed journals or in conference proceedings


(c) Papers presented at meetings, but not published in conference proceedings


**Interactions/Transitions**

*Participation at meetings:* Invited to and participated in Terahertz review at University of Adelaide, December 2004.

*Consultative and advisory functions:* none during the period

*Transitions:* Our technology is being transitioned to a startup company, Tera-X, LLC.

*New discoveries:* (none this year).

*Honors/Awards:* none during the period
References


