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11. SUPPLEMENTARY NOTES

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13. ABSTRACT (Maximum 200 words)

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.

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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 simulants (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.

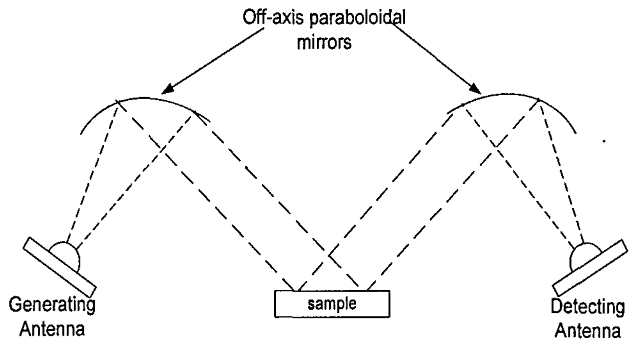
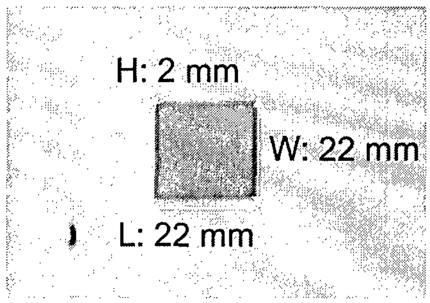


Figure 1. Reflection setup for measuring absorption of bacterial spore samples.



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.

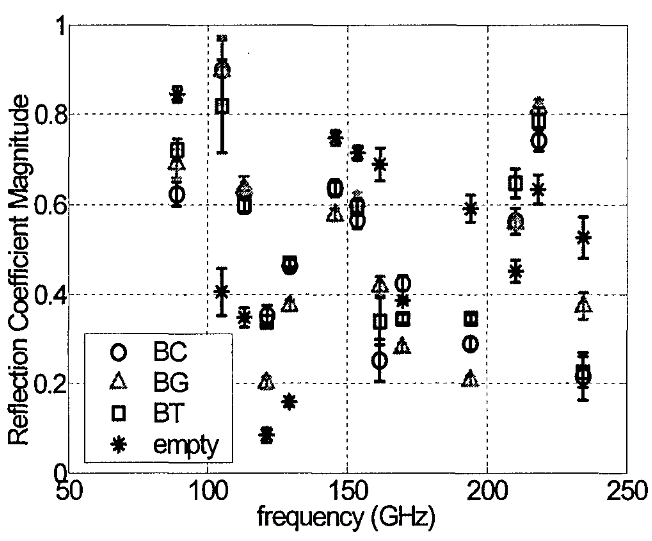


Figure 3. Results of broadband reflection measurements from samples detailed in Fig. 2. Ten trials were conducted on each sample; the error bars show +/- one standard deviation. Note that distinguishability of samples increases at higher frequencies.

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).

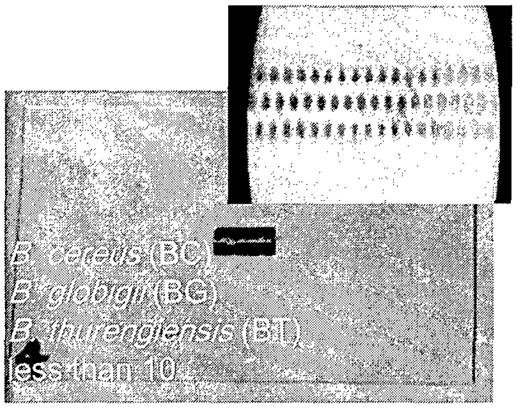


Figure 4. Micropillar array mounted on glass slide (inset: close-up of array), with list of bacterial spore types and mass in μg.

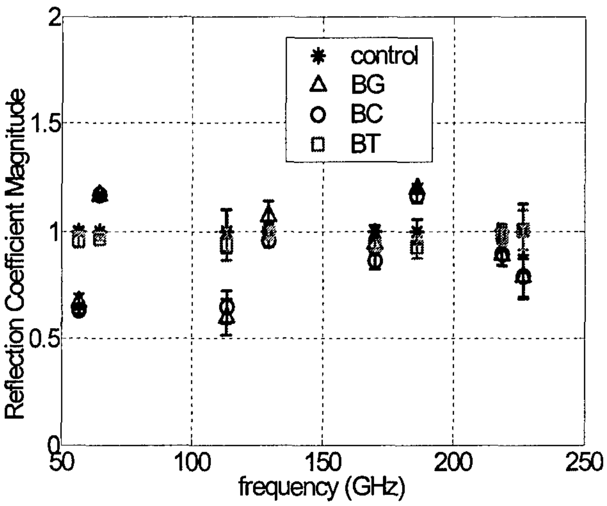


Figure 5. Results of broadband reflection measurements from samples detailed in Fig. 4. Ten trials were conducted on each sample; the error bars show +/- one standard deviation. Note that distinguishability of samples is less than that possible with greater sample masses (Figure 3).

Personnel supported

Name	Function	Honors	Awards	Degrees
Van der Weide, Daniel	PI	None this term	None this term	N/A
Choi, Min	Grad student	None this term	None this term	Ph.D. (finishing this year)
Sun, Kae-Oh	Grad student	None this term	None this term	Ph.D. (finishing this year)
Kelvin Fu	Post-doctoral researcher	None this term	None this term	Ph.D.
Alexander Kozyrev	Post-doctoral researcher	None this term	None this term	Ph.D.
Charles Paulson	Post-doctoral researcher	None this term	None this term	Ph.D.
Taylor, Kimberly	Grad student	None this term	None this term	Ph.D.
Bettermann, Alan	Researcher	None this term	None this term	N/A

Publications

(a) Manuscripts submitted, but not published

(NONE)

(b) Papers published in peer-reviewed journals

A. B. Kozyrev, H. J. Kim, A. Karbassi, and D. W. van der Weide, "Wave Propagation in Nonlinear Left-Handed Transmission Line Media," *Applied Physics Letters*, vol. 87, pp. 121109-11, 2005.

A. B. Kozyrev and D. W. van der Weide, "Nonlinear Wave Propagation Phenomena in Left-Handed Transmission Line Media," *IEEE Transactions on Microwave Theory and Techniques*, vol. 53, pp. 238-45, 2005.

H. J. Kim, A. B. Kozyrev, A. Karbassi, and D. W. van der Weide, "Linear Tunable Phase Shifter Using a Left-Handed Transmission Line," *IEEE Microwave and Wireless Component Letters*, vol. 15, pp. 366-68, 2005.

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

K. Taylor and D.W. van der Weide, "Ultra-Sensitive Microwave Detection of Protein Conformational Changes," IEEE MTT-S Int. Microwave Symp. Dig., Vol 3, 1583 (2004).

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

D. W. van der Weide, "Antennas and electronics for sub-THz stand-off spectroscopic imaging," **Invited Presentation** at University of Adelaide, December 2004.

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

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