White Paper **March 06, 2010**

Detection of explosives and IEDs

1. Background

Standoff detection of explosives using terahertz (THz) radiation is promising because those materials typically display diagnostic series of molecular THz resonances, yet many packaging or concealment materials are semi-transparent at such frequencies. The physical problem of interest is therefore to understand the THz interaction within target materials (by, for example, granular morphology) or near the target (by packaging) affects observation of characteristic resonances. This project is a coordinated program of experiments, based on broadband THz generated from electro-optic dendrimer [1]. With this approach, we will develop and test methods for THz spectral signature of explosives and common packaging and target material morphologies.

Recently, the National Research Council (NRC) has conducted an investigation for the Transportation Security Administration (TSA) and published a committee report titled, "Assessment of Millimeter-Wave and Terahertz Technology for Detection and Identification of Concealed Explosives and Weapons" [2]. They mentioned, "This report focuses on the currently maturing millimeter-wavelength and terahertz imaging and spectroscopy technologies that offer promise in meeting aviation security requirements through airport screening. The millimeter-wave through the terahertz region is now the subject of aggressive university research driven by the availability of short-pulse generators, which produce a wide spectrum of frequencies through this region. The committee believes that millimeter-wave/terahertz technology has potential for contributing to overall aviation security but that its limitations must be recognized."

ARP has recently demonstrated a high average power terahertz technology that could break some of the barriers as outlined in ref. [2] in applying terahertz spectrometry for molecular signature recognition of explosives/IEDs. ARP's terahertz spectrometer is enjoying success in several areas as documented in the white paper supplied before [3]. ARP is also applying its terahertz technology to help fight cancer in collaboration with the SAIC-Frederick [4].

2. Main Tasks for Remote Identification of IRD/Explosives

The key factor in identification of the IEDs and other explosives is the molecular signature recognition of the compounds from trace amount of residues. To achieve higher success rate and low false alarm, the technology must have very high sensitivity to pick up the right signature from very low amount of material remaining in the residue. To this end, ARP has demonstrated an ultra sensitive capability, as low as pico-molar to femto-molar [3, 5]. The remaining tasks will incorporate selectivity of the explosive materials by generating their terahertz spectral signature and building a library. Such library will also be useful for other initiatives. ARP is discussing with the Department of Homeland Security who is arranging to send explosive samples for testing; this will help us to generate preliminary data.

Another task will involve the design and implementation of an appropriate mechanism for testing and installing the devices in the field. Since terahertz is capable of penetrating through fog and sand storm, this technology is an ideal candidate for remote identification of IED/explosives.

Two more key factors for extended range detection are: terahertz power and terahertz range. ARP has demonstrated high average power (a few milliwatts) continuous (CW) terahertz having a wider range (~10 THz). However, the terahertz power may be further enhanced via a chip based terahertz generator conceptualized at ARP. This will involve fabrication of terahertz chip from dendrimer that will enable terahertz amplification via waveguide technology. ARP is discussing with the Penn State University's materials research institute (MRI) to fabricate a prototype chip. However, the tasks of the current proposal are not dependent on the chip development; the existing THz emitter will be able to accomplish the tasks.

With the above capabilities, ARP technology is uniquely positioned to tackle the challenges of the remote detection of IED/explosives. Fig. 1 shows a scenario where the spectrometer can be installed on a truck and the detection can be conducted at the field. It can also be installed on airborne vehicles. With further development it can also be extended to remote detection of buried explosives and/or land mines.

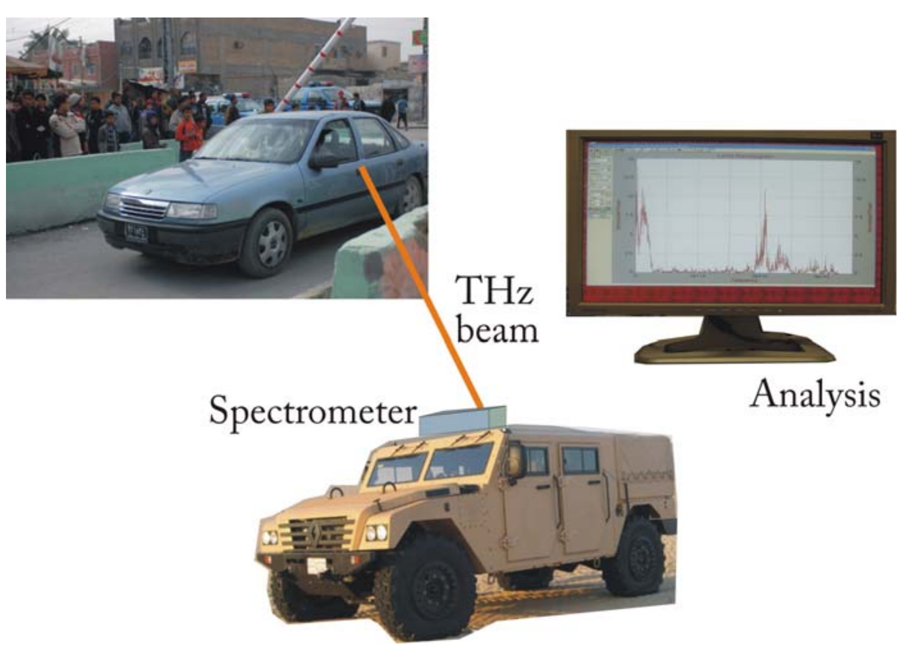

Fig. 1. An installation scheme for the spectral monitoring system in the field.

3. Review of the NRC committee report [2]

It is worth reviewing the findings of the NRC committee report [2] for further considerations of the development proposed by ARP. The report made the following conclusions:

1. The technology base for millimeter-wavelength/terahertz security screening is expanding rapidly internationally, yet there is insufficient technology available to develop a system capable of identifying concealed explosives.
2. Millimeter-wavelength/terahertz technology has potential for contributing to overall aviation security, but its limitations need to be recognized. It will be most effective when used in conjunction with sensor technologies that provide detection capabilities in additional frequency regions.
3. Millimeter-wavelength/terahertz technology in portal applications has been demonstrated for detecting and identifying objects concealed on people.
4. Millimeter-wavelength/terahertz image quality raises personal privacy issues that need to be addressed.
5. Millimeter-wavelength/terahertz technology and x-rays provide images of similar quality. However, millimeter-wavelength/terahertz energy has the safety benefit of being non-ionizing radiation, while x-rays are ionizing radiation. Millimeter-wavelength/terahertz energy cannot penetrate metal objects.
6. Universities, national laboratories, and the commercial sector (both national and international businesses) continue to increase investment in millimeter-wavelength/terahertz technologies for security, medical, nondestructive inspection, and manufacturing quality-control applications.
7. A decision by the Transportation Security Administration (TSA) to invest in an imaging portal depends on the potential threat posed by passengers carrying either weapons or explosives or other material. The cost of a system, the probability of detection, the false-alarm rate, and the throughput versus

The committee also made the following recommendations to the TSA:

1. To perform an accurate assessment of the applicability of millimeter-wavelength/terahertz-based technology to explosive detection, the TSA will need to do the following: (1) decide on the range of materials to be detected, (2) assess the state of knowledge of what chemical structures and/or features of the scope of materials lend themselves to detection by millimeter-wavelength/terahertz-based spectroscopy, (3) assess the presence of these features in other common materials (such as clothing) within the range of uncertainty for such features, and (4) assess the contribution of additives to explosives to the millimeter-wavelength/terahertz signature.
2. The TSA should examine how millimeter-wavelength/terahertz technology can be employed with other technologies to enhance the detection of weapons and explosives.

3. The TSA should commence developmental and operational testing of millimeter-wave-based portals to assess their effectiveness and suitability.
4. As with x-ray-based passenger imaging, the TSA needs to address issues associated with personal privacy raised by millimeter-wave/terahertz imaging.
5. The TSA should actively pursue joint projects through agreements such as cooperative research and development agreements with industry, academia, the Department of Defense, and the national laboratories to benefit from their investments in millimeter-wavelength/terahertz technology and applications.
6. The TSA should follow a two-pronged investment strategy:
    - Focus on millimeter-wave imaging as a candidate system for evaluation and deployment in the near term, and
    - Invest in research and development and track national technology developments in the terahertz region.

Thus a ground work has already been laid down by the NRC. Although the work was specifically done for the TSA, the recommendations can be utilized and tailored to fit the needs of the DoD for the intended purposes.

4. Summary

The NRC report and other contemporary literature abundantly indicate the need of a well developed terahertz technology for IED/explosives identification. The capability of "remote identification" is very important to avoid terrorist attack and related accidents that are now a part of the news on a regular basis. ARP has developed the basic technology that will be well suited for the above purposes. A relatively small budget requested for the development of a prototype system and its testing is well worth considering the expected return in terms of saving the lives and resources. Therefore, your consideration for approving this project is kindly requested.

5. References

[1] Anis Rahman, "Stimulated Emission of Terahertz Radiation from Electro-optic Dendrimer," Paper Number: 7601-11, SPIE conference on SPIE OPTO: Optoelectronic Materials, Devices and Applications, January 23-28 2010, SPIE Photonics West, San Francisco, CA.

[2] "Assessment of Millimeter-Wave and Terahertz Technology for Detection and Identification of Concealed Explosives and Weapons," Committee on Assessment of Security Technologies for Transportation National Materials Advisory Board Division on Engineering and Physical Sciences, ISBN: 0-309-66849-2, 88 pages, 8 1/2 x 11, (2007). http://books.nap.edu/openbook.php?isbn=0309104696.

[3] ARP white paper 2010: http://arphotonics.net/ARP_white_paper_02092010.pdf.

[4] “SAIC-Frederick and Applied Research & Photonics Collaborate on Advancing Applications of Terahertz Spectrometry,” http://arphotonics.net/ATPI_Applied_Research_news_release_Final.pdf

[5] Anis Rahman, Bruce Stanley, Anuk K. Rahman, “Ultrasensitive label-free detection and quantitation of DNA hybridization via terahertz spectrometry,” Paper Number: 7568-8, SPIE conference on Imaging, Manipulation, and Analysis of Biomolecules Cells, and Tissues VIII, January 23-28 2010, SPIE Photonics West, San Francisco, CA.

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