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Session: Advances in Low-Cost, Fieldable All-Threat Sensing
DTRA Session Chair: Dr. Brandi Vann
When encountering unknown substances in the field, first responders have few simple, low-cost approaches to quickly triage the substance by category (e.g., chemical threats, explosives, narcotics) before taking further action. The easiest and most rapid approaches include paper test strips (pH, M8, oxidizer) but these have limited libraries and color interpretation issues. Innovative technologies are sought to rapidly cover a wide range of threats encountered by warfighters and first responders, to ideally include, or be expandable to: (i) Chemical warfare agents (CWAs) and precursors (ii) Toxic industrial chemicals (TICs) (iii) Explosives and explosives precursors (iv) Narcotics. Detection approaches that reduce cost, complexity, and logistical burden are of highest interest.

Title
A new, hand-held, in situ, sensor for real-time, reagentless, non-contact detection of chemical, biological, and explosive substances on surfaces.

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Abstract:
Real-time, in situ, assessment of suspicious substances on surfaces is an important capability needed by warfighters and first responders. It is also important to be able to performing these assessments without contact with the suspicious substance or use of reagents. This paper presents the status of work conducted under DTRA and Army funding to develop a hand-held, 1 m to 5 m standoff, optical sensor which can detect and classify trace and bulk concentrations of a wide range of chemical, biological, and explosives (CBE) materials in real-time and full daylight conditions with a single, fully integrated, device weighing less than 8 pounds, including batteries.

Present hand-held surface contamination sensors predominantly employ visible or near IR Raman methods, not usable in daylight conditions except in essential contact with the suspicious powder. They also are limited in the number of detectable analytes because of Raman signal obscuration by fluorescence. They also cannot detect biological substances. Biological detection is currently limited to methods that require collection of samples to be used with immunoassays or PCR, both of which require bulky and expensive equipment and expensive reagents with limited shelf life and restrictive environmental conditions for storage and use. Other hand-held sensors such as PID and IMS sensors detect airborne gases and vapors, which may be a result of evaporation of surface material. But they do not detect substances on surfaces which have low vapor pressure or at standoff distances. PIDs have no specificity, and IMS sensors are subject to a wide range of interferents and confusants.

The sensor method being described here uses a fusion of Raman and fluorescence emissions excited in the deep UV. There are five main advantages of excitation in the deep UV compared to near-UV, visible or near-IR counterparts. 1) Excited in the deep UV below 250 nm, Raman emission occur within a fluorescence-free region of the spectrum, eliminating obscuration of weak Raman signals by fluorescence from targeted or surrounding materials. 2) Because Raman and fluorescence occupy separate spectral regions, detection can be done simultaneously, providing a much wider range of information about a makeup of a target substance. Raman spectroscopy provides information about molecular bonds within the targeted substance, while fluorescence spectroscopy is a much more sensitive method that provides information regarding the electronic configuration of target molecules. 3) Rayleigh law and resonance effects increase Raman signal strength and sensitivity of detection. 4) When excitation is below 250 nm, fluorescence emissions cover the full spectral range of any material, without alteration by strong Raman bands. This enables identification information, especially of biological materials. 5) Penetration depth into target in the deep UV is short, providing physical and spectral separation of a target material from its background matrix material.

Photon Systems, in collaboration with JPL, has been developing combined Raman and fluorescence methods for many years, focused on the detection advantages of excitation in the deep UV below 250nm. This has enabled many instruments deployed to extreme environments on Earth and an upcoming lander mission to Mars.