Standoff detection of bioaerosols from laser-induced fluorescence

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Standoff sensing performed in real time by exploiting the spectral properties of bioaerosols facilitates classification of detected materials.

Real-time standoff biological agent detection—i.e., the detection of biological agent clouds at some distance from the target—is now a key requirement for defense and security. Of the several technologies developed to address this challenge, none is presently able to provide efficient protection against such threats. Light detection and ranging (lidar) technologies, based on the transmission of laser pulses and analysis of the return signal, have demonstrated impressive capabilities in aerosol standoff sensing. However, higher sensitivity and lower false alarm rates are required to make them relevant for defense and security applications. High sensitivity is needed to detect low concentrations at standoff distances. Low false alarm rates are imperative for efficient operational scenarios where the capacity to discriminate between an inoffensive and a potentially threatening bioaerosol cloud is paramount.

Single-wavelength elastic backscatter lidar techniques have demonstrated valuable capabilities in cloud mapping and long-range low-concentration aerosol detection, but are unable to distinguish between clouds of different compositions having similar aerosol size distributions. Passive infrared spectroscopy, polarization-sensitive lidar, differential elastic scattering, and laser-induced fluorescence (LIF) are all promising contenders with respective advantages and drawbacks.

We are working on a new approach based on spectrally resolved UV-LIF range-gated detection with the aim of optimizing sensitivity and discrimination capability. The schematics of the system, called SINBAHD (Standoff Integrated Bioaerosol Active Hyperspectral Detection), are shown in Figure 1. It consists of a UV laser source, a beam expander, a folding mirror (FM), a steering mirror, and a 30cm-diameter Newtonian telescope that collects the returned radiation and focuses it at the entrance slit of an imaging spectrometer. An intensified charge-coupled device (ICCD) camera detects the dispersed radiation at the exit window of the spectrometer. The intensifier gate is synchronized with each laser pulse fired, with a delay defining the range of the probed atmospheric cell based on the light time-of-flight. The intensifier sensitivity combined with the 16bit dynamic range of the camera and the signal spectral distribution is very attractive for detecting low signal levels. The elastic scattering is also sampled (SBS) and directed to a photomultiplier (PM) tube, connected to a transient recorder (Licel). It provides elastic scatter returns as a function of range. This information is used to configure the width and position of the intensified range gate where the LIF is collected.

The SINBAHD sensor is used to characterize fluorescent aerosols during open-air releases. For this particular type of test, the recorded spectra include fluorescence emission from various types of biological aerosols and Raman scattering from common atmospheric molecules. Multivariate analysis is then used to represent the collected inelastic spectra as a linear combination of

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normalized spectral signatures to scale their respective contributions (signature amplitude). The efficiency of this analysis relies on a spectral library first acquired from short-range, well-controlled, high-concentration releases. The fluorescence signature of a given material may be influenced by several parameters, such as its origin, growth and preparation method, dissemination process (wet or dry), or even by the prevailing weather conditions during dissemination.

In our experiments, we investigated the spectral signatures of Bacillus subtilis var. niger (BG) samples of different origin, state, preparation, and/or dissemination method (see Figure 2). Two different samples were compared: ‘old BG,’ obtained from the Dugway Proving Ground (DPG) in the United States, and disseminated in a wet state by a Micronair blower at DRDC Suffield, Alberta, Canada, in May and September 2001; and ‘new BG’ originating from Denmark and disseminated in a dry state during three different types of releases (point, puff, and aerial) at DPG when the Joint Biological Standoff Detection System (JBSDS) Demo II trial was held in June 2005. The signatures acquired on these two occasions were fairly consistent with each other, even though the samples had major characteristic differences. The experiments showed that a major goal of the newly developed SINBAHD system, i.e., the standoff detection of bioaerosol threats, could be met since it was able to exploit the spectral signatures of the various BG species.

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