QUANTUM TECHNOLOGIES, METAMATERIALS, AND THE FUTURE OF CB SENSING

Waveguide-enhanced Raman Spectroscopy for Field Detection of Threat Vapors

Erik Emmons U.S. Army DEVCOM Chemical Biological Center **Phillip Wilcox** U.S. Army DEVCOM Chemical Biological Center **Kevin Hung** U.S. Army DEVCOM Chemical Biological Center **Erik Roese** U.S. Army DEVCOM Chemical Biological Center **Ashsih Tripathi** U.S. Army DEVCOM Chemical Biological Center **Jason Guicheteau** U.S. Army DEVCOM Chemical Biological Center **Nathan Tyndall** Naval Research Laboratory **Marcel Pruessner** Naval Research Laboratory **Todd Stievater** Naval Research Laboratory

Compact, non-contact optical detection of threat materials is an important capability for the military and homeland security to protect soldiers and civilians. Waveguide-enhanced Raman spectroscopy (WERS), a photonic integrated circuit (PIC) sensing methodology, is being developed for field detection of vapors from chemical warfare agents, explosives, and narcotic threats. Conventional Raman spectroscopy is difficult to utilize for the detection of low concentration vapor-phase analytes due to the weak scattering cross sections and small numbers of target molecules. In order to overcome this challenge, WERS combines long, low-loss evanescent waveguides with sorbent coatings for analyte partitioning to enhance signal levels and allow for detection of low concentrations of vapor-phase analyte . A large fraction of the Raman scattering from molecules sorbed into the evanescent field of the waveguide will be efficiently recollected into the waveguide mode.

Low-loss, low-fluorescence, single-mode, silicon nitride spiral waveguides with path lengths of several centimeters are used to obtain high signal levels with visible and near-infrared excitation. Drawing on over two decades of advancement in miniaturization and sensitivity of optical spectrometers, compact single-mode fiber-coupled spectrometers with high sensitivity are being utilized for detection of the Raman scattered light. Thermoelectrically cooled charged-coupled device (CCD) detectors enable stable, low-noise, and high quantum efficiency spectral measurements. Performance comparable to that obtained with large benchtop spectrometers is observed. Fiber array attachment to the PICs enables easy and stable optical coupling of the laser and spectrometer to the sensor. The spiral waveguides are coated with functionalized polymer sorbents suitable for concentrating relevant classes of threat materials. The sorbents are deposited using piezoelectric microdispensers to allow for controlled deposition of thin films without the need for spin-coating. Raman chemical imaging and optical film thickness measurements are used to characterize the uniformity of the sorbent polymers on the waveguides. Library spectral matching can be used in combination with the selectivity of the sorbent materials to provide discrimination of the materials absorbed by the polymer coatings. The ultimate objective is development of a prototype handheld WERS sensor system suitable for defense and security applications in the field. This would add an important tool for situational awareness and warfighter protection.

This work was partly supported through the U.S. Army Explosives Forensics Program. This research was additionally funded by the Defense Threat Reduction Agency - Joint Science and Technology Office, project #CB11261, Mr. Tyler Miller.