ALERT F2: Vibrational Spectroscopy Standoff Explosives Detection

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Abstract

The objective of the F2-F is to develop Standoff (SO) Vibrational Spectroscopy detection of highly energetic materials (HEM) and homemade explosives (HME) in terms of range, in detection limits and discrimination/quantification studies.

An Open-Path Standoff Detection System was designed by coupling a mid-IR reflectance telescope coupled to a FTIR spectrometer. HEM deposited on metal surfaces were detected using this method. Standoff detection experiments on metal surfaces were carried out in passive and active modes. The samples analyzed were placed at different distances up 55 m and surface concentrations of 50 μg/cm^2.

A SO Raman system was built from commercial off-the-shelf components. Significant improvements in design of home built telescope coupled Raman system resulted in detection of HEM at very long ranges (> 140 m), bulk detection of ammonium nitrate (AN) and TNT detection of samples of 2 mm in diam. at 60 m range.

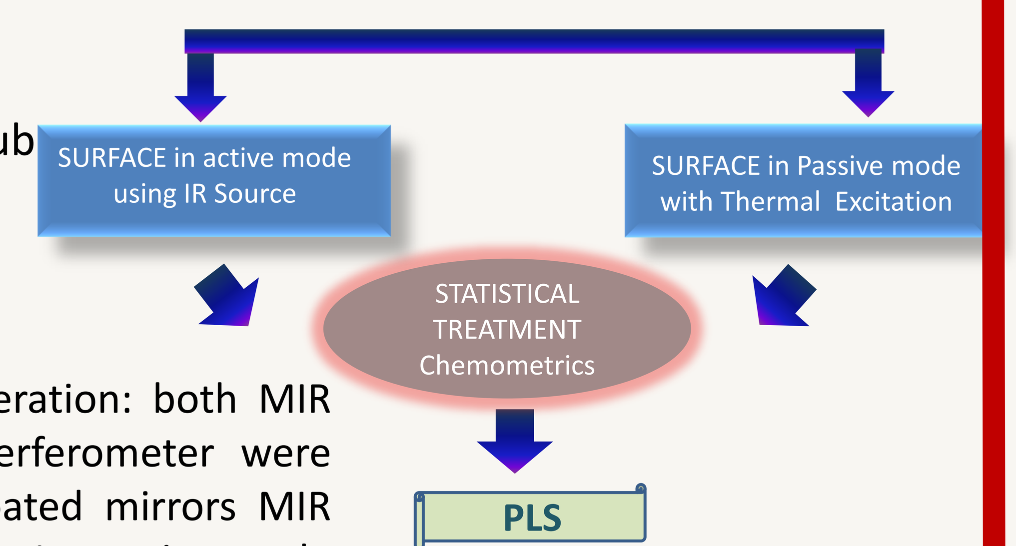
Relevance

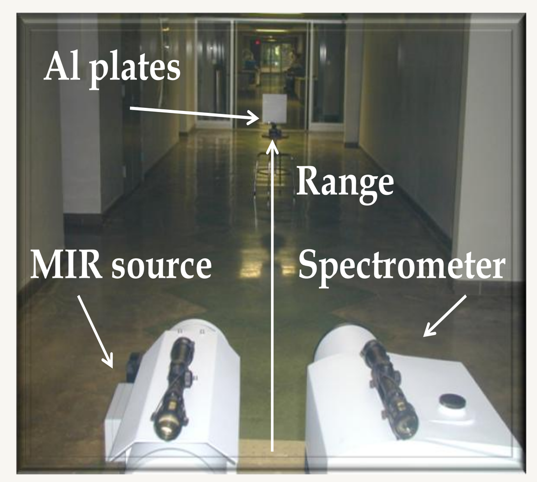
Using a well designed Raman/OP-FTIR SO detection system, vibrational signatures of HEM/HME can to be recorded at target distances of several meters to hundreds of meters. SO Raman/FTIR detection allows for real time analysis, without sample preparation, no human contact, solventless and complementary results can be obtained, allowing for sensor fusion applications. Possible damage caused by terrorist action, in the case that the HEM is detonated can be minimized by remote detection of HEM.HME, CHEMBIO threats and others.

Technical Approach

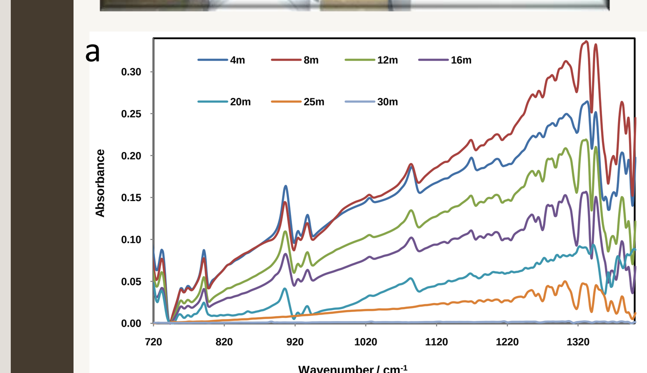
OP-FTIR detection of HEM

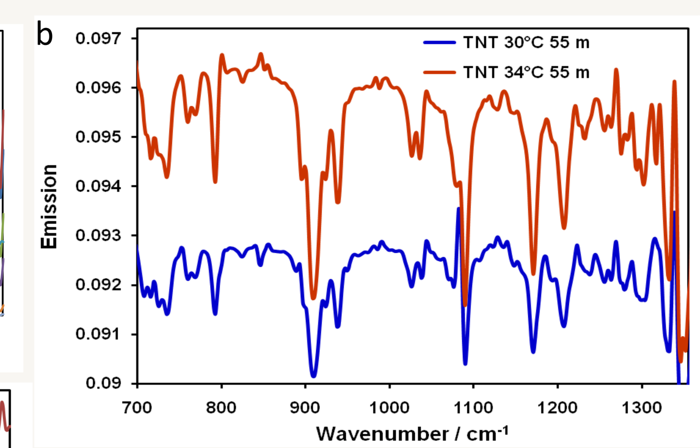
1-Dissolve HEM in dichloromethane
2-Smear sample on substrate using a Teflon stub
3- OP-FTIR detection: active and passive mode

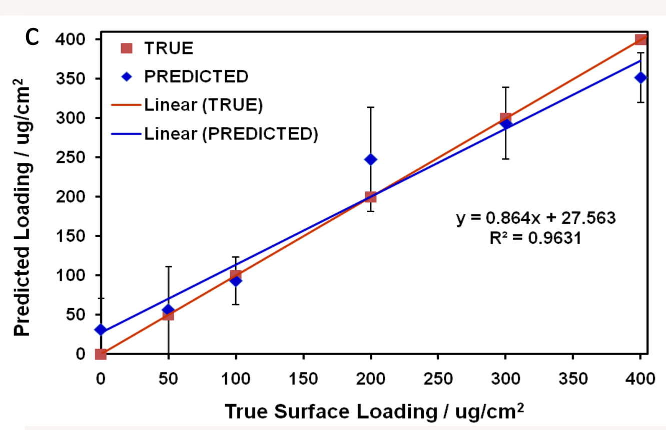


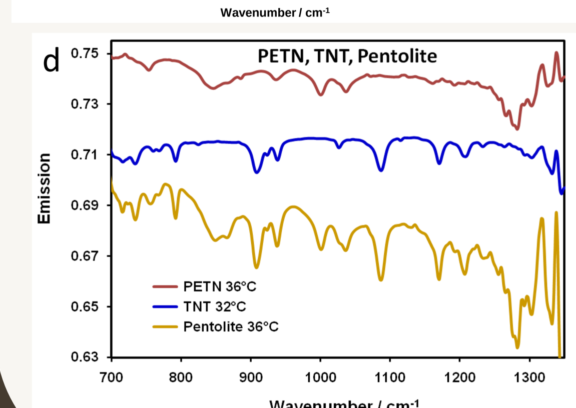


In active mode operation: both MIR source and FT interferometer were coupled to gold coated mirrors MIR reflective telescopes. In passive mode only the IR spectrometer was used.

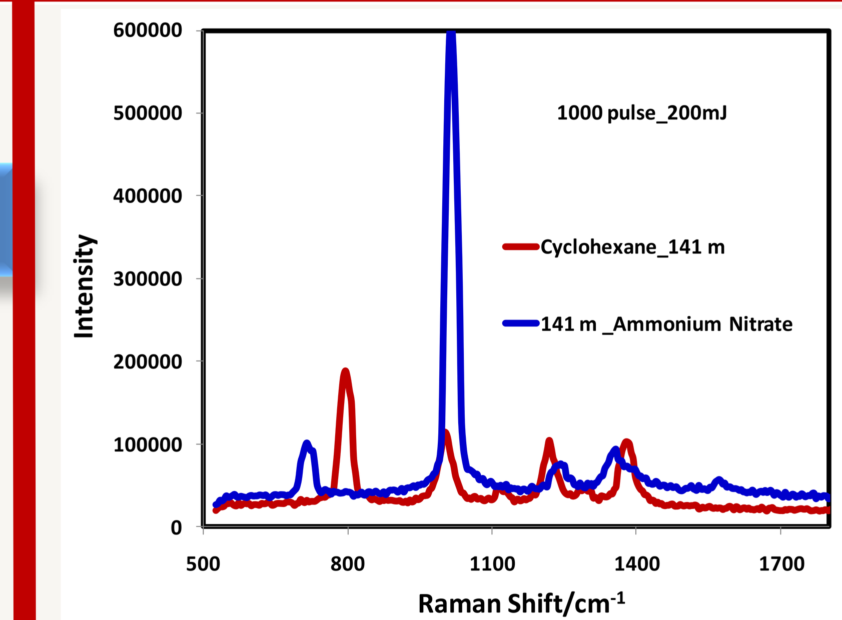




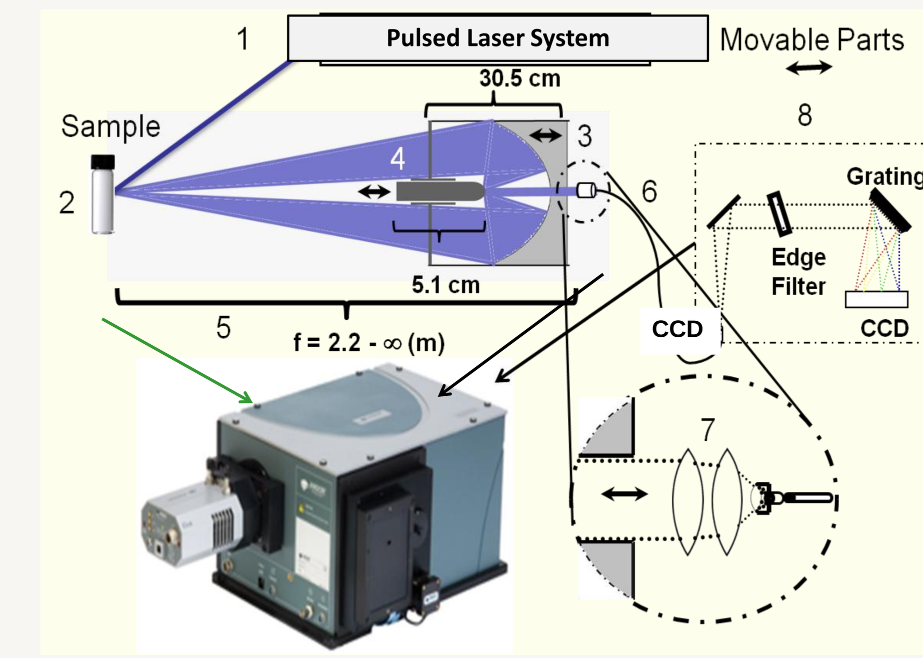




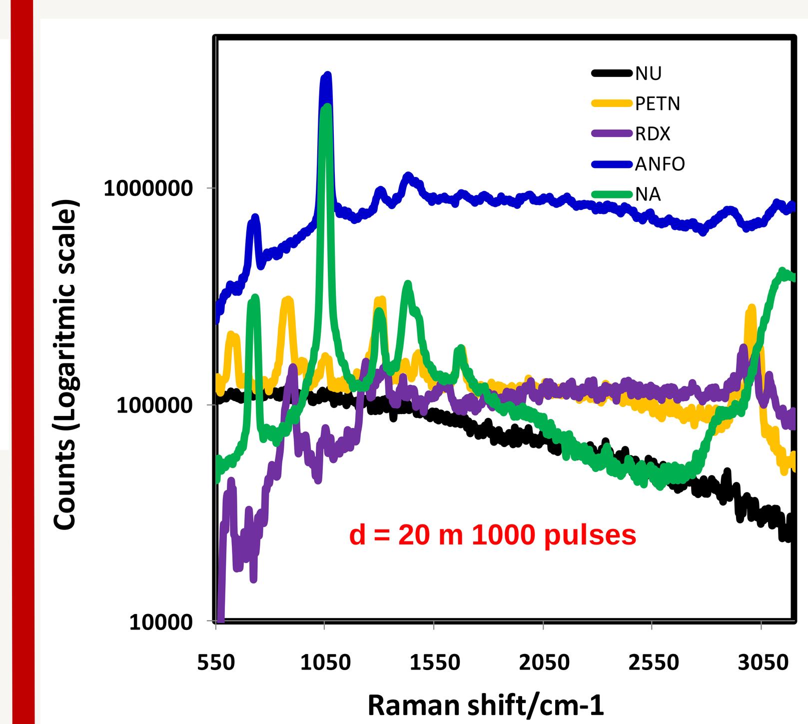
(a)Active mode OP-FTIR spectra of TNT, 400 μg/cm^2;
(b) Passive mode OP-FTIR spectra of TNT;
(c) PLS cross validation for 30 m;
(d) Emissions of heated PETN, TNT and Pentolite at 20 m.



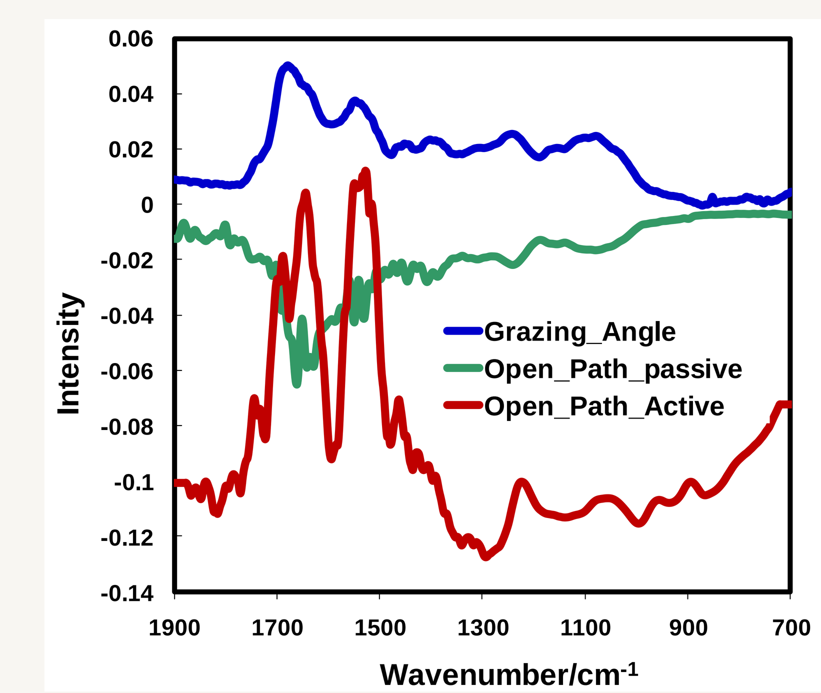
SO Raman of AN and cyclohexane at 141 m



Experimental setup for standoff Raman detection



Standoff Raman of other HEM at 20 m



OP-FTIR spectra of *Bacillus thuringiensis* endospores (10^7 cfu/mL) at 1.5 m

Accomplishments Through Current Year

- Active and passive measurements of remote Open Path-FTIR detection of traces of HEM on Al plates.
- SO Raman detection of HEMs at very long ranges (> 140 m). Bulk detection of AN.
- TNT Detection samples 2 mm in diam. at 60 m range.
- Discrimination and quantification studies: for both remote SO Raman and OP-FTIR detection
- Began 2 transition projects (YR-3) and planned 2 more (YR-4) in collaboration with industries in MA: Agiltron, Block Engineering, Headwall Photonics and EOS Photonics.

Future Work

- Make standoff detection on other substrate or materials of the real world, such as leather, clothing, handbag and wood using OP/FTIR
- Use a Quantum Cascade Laser (QCL) coupled to IR telescope as excitation source for active detection.

Opportunities for Transition

Defense and Security agencies as well as private sector are highly interested in finding new ways of detecting HEM/HME, hazardous chemicals TIC, TIM and microorganisms. Food industries, environmental protection agencies and Pharmaceutical and Biotechnology Industries will also benefit from remote detection of CHEM-BIO threats.

Patent Submissions

1. Surface Enhanced Raman Spectroscopy Gold Nanorods substrates for detection of 2,4,6-trinitrotoulene and 3,5-dinitro-4-methylbenzoic acid explosives
2. Growth of Ag, Cu, Pt and Au Nano-Structures on Surfaces by Micro-Patterned Laser Image Formation

Publications Acknowledging DHS Support

- Ortiz-Rivera, W; Pacheco-Londoño, L.C.; Hernández-Rivera, S. P., Remote Continuous Wave and Pulsed Laser Raman Detection of Chemical Warfare Agents Simulants and Toxic Industrial Compounds, (2010), Sensing and Imaging: An International Journal, 11(3): 131-145.
- Ramírez, M.L., Ortiz-Rivera, W., Pacheco-Londoño, L.C. and Hernández-Rivera, S.P. Remote Detection of Hazardous Liquids Concealed in Glass and Plastic Containers, (2010), IEEE J. Sensors, 10 (3): 693-670.
- Pacheco-Londoño, L., Ortiz-Rivera W., Vibrational spectroscopy standoff detection of explosives, (2009), Analytical and Bioanalytical Chemistry, 395(2): 323-335.
- Hernandez-Rivera, S.P., Castro-Suarez, J.R., Pacheco-Londoño, L.C., Primera-Pedrozo, O.M., Rey-Villamizar, N., Vélez-Reyes, M. and Diem, M. Mid-Infrared Vibrational Spectroscopy Standoff Detection of Highly Energetic Materials: New Developments, Spectroscopy 2-9, April, 2011

Other References

For more information, please go to:
http://academic.uprm.edu/ccsde/

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