



Miniaturized Hybrid Sensor for Multiple Threats Detection

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CEM MSR

Problem



- **Detection of chemical, biological, and explosive threats has become increasingly difficult due to continuous changes of their characteristics and operating principles**
 - **Continuous changes require that the detector be adaptable to new threat materials**

- **An effective solution requires widely deployable sensors with good detection capability**
 - **High probability of detection, low false/nuisance alarms, and high selectivity are needed**
 - **Rugged, miniaturized sensors enable wide deployment**
 - **Effectiveness in wide environmental conditions**
 - **Operation on unmanned systems**

- **Successful detection enables appropriate response to neutralize the threats both in the homeland and in the theater**

Background



Evolving threats require multiple modalities of detection using an orthogonal sensor combination

Present	Near-Term 2-3 Year	Future ~ 5yr.+
 <p>Trace Portal ~ \$120k</p>	 <p>Portable Raman uProbe ~ \$25k</p>	 <p>MEMS Array Sensor < \$1k</p>
 <p>Transportation Security Administration</p>	<p>Susan Hallowell</p>	<p>April 6, 2004</p>

R&D trends: miniaturized sensors with high sensitivity and selectivity for rapid threat detection and wide deployment



Rugged, miniaturized sensors operating in difficult environments are needed to mitigate evolving threats

Objective

- **Develop a hybrid sensor in a compact package for rapid detection of threats, especially trace explosives**
 - **Combine the best features of complementary technologies to achieve high detection sensitivity as well as high selectivity; these technology components respond effectively to multiple threats**
 - **Achieve performance that significantly supersedes currently available sensors, especially for trace detection (e.g., Ion Mobility Spectrometer [IMS], electron capture detector, and Raman)**

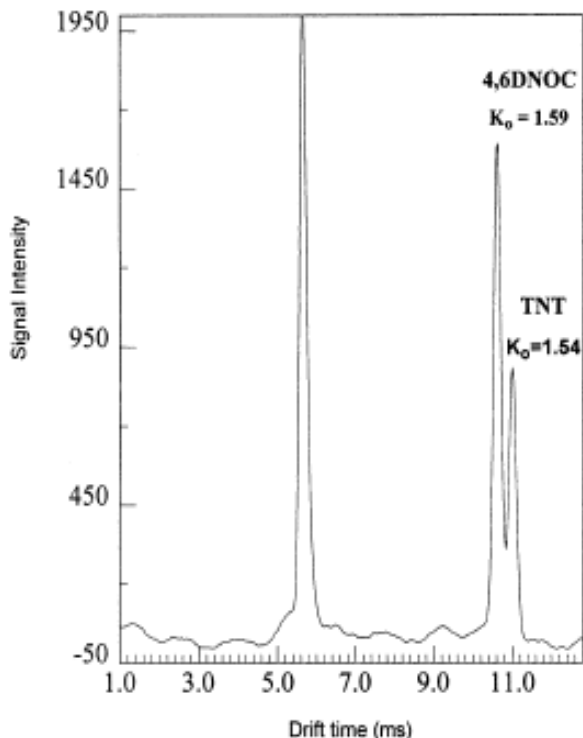
Activities*

- **Design a small Ion Mobility Spectrometer (IMS) and Surface-Enhanced Raman Spectrometer (SERS) as subcomponents to a hybrid sensor system**
 - Design an optimal IMS system through modeling and experiments: examine electric field uniformity, space-charge effects, and their role on miniaturization
 - Design SERS substrate and build comprehensive spectral library
- **Develop, build, test, and integrate subcomponents**

*Collaboration: Adrian Mariano, Steven Fairchild, Charles Bradshaw, Gerardo Garcia, Washington State University, and Drexel University

Highlights

IMS offers rapid response and good sensitivity for trace detection

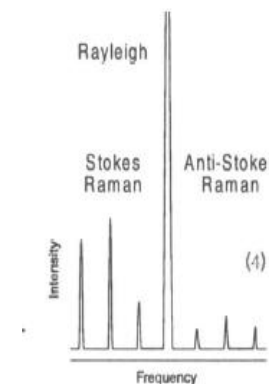
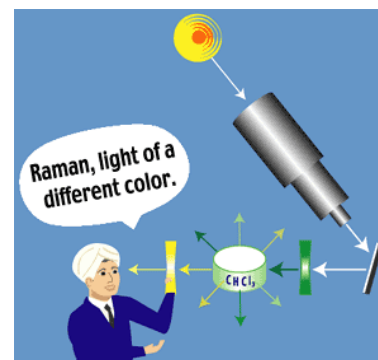


Mobility K_0 is determined from drift time t_d

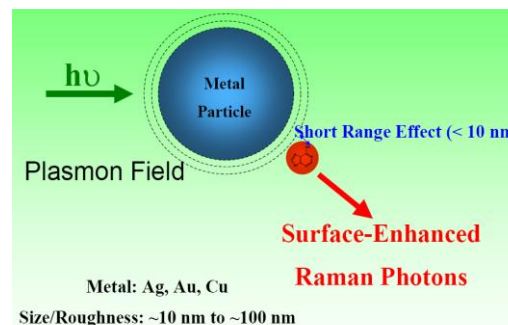
Wu et al., Talanta, vol. 57, 2002

- Note the proximity of two peaks in IMS spectrum
 - Close mobility values of DNOC, a non-threat material, and TNT create false alarms
- Orthogonal sensors needed to improve selectivity

SERS enables trace detection with high selectivity



Bulk Raman Spectra: sample ~ mg

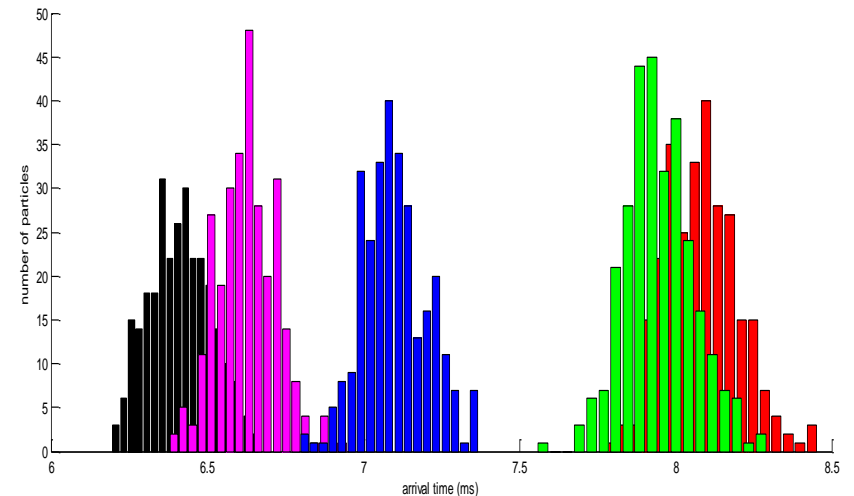
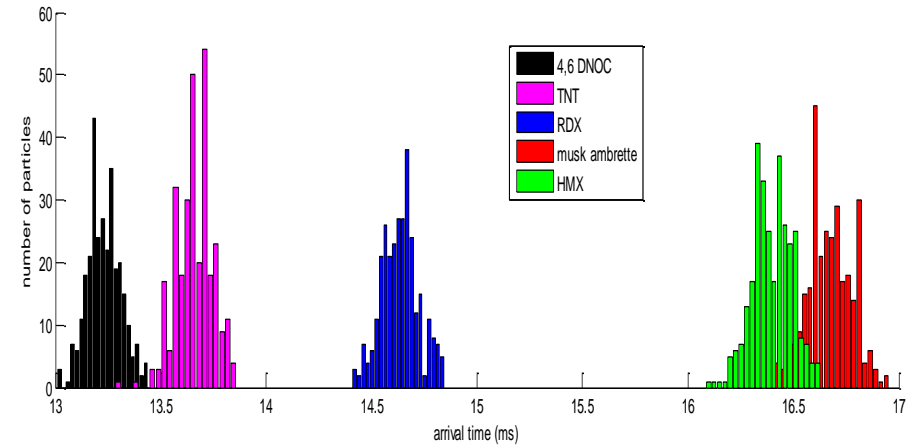
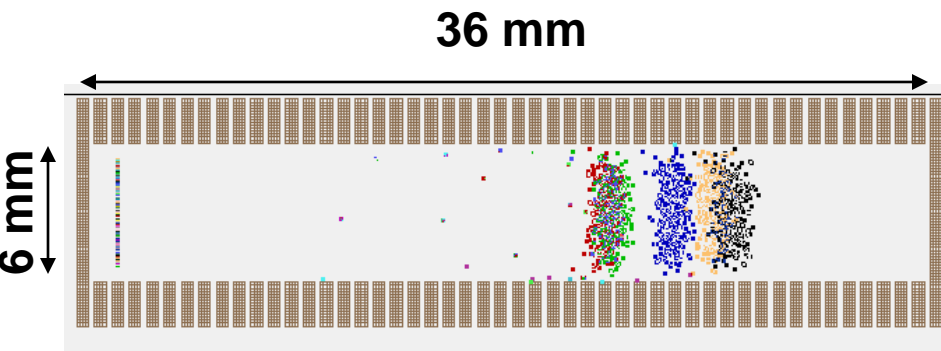
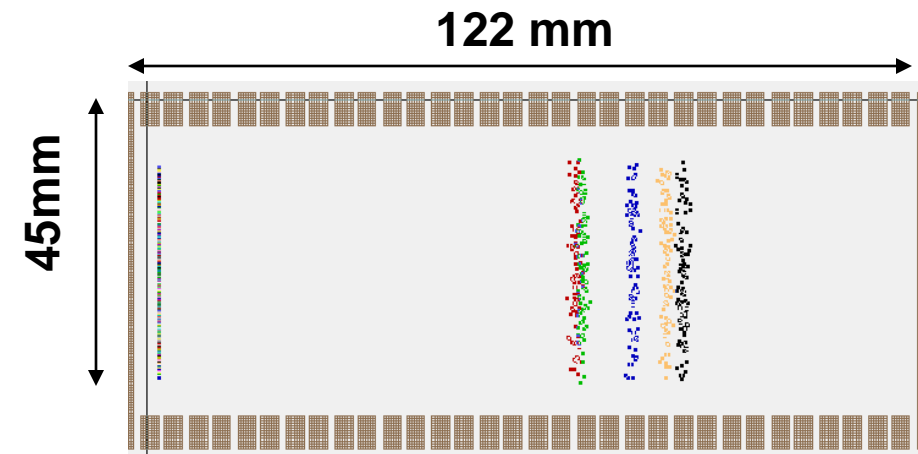


W. McGann, HSARPA Tech Workshop, 2004

- Due to E^4 dependence in SERS compared to E^2 in bulk Raman, small increase of local E-field strongly increases the scattered signal enabling sub-picogram level detection

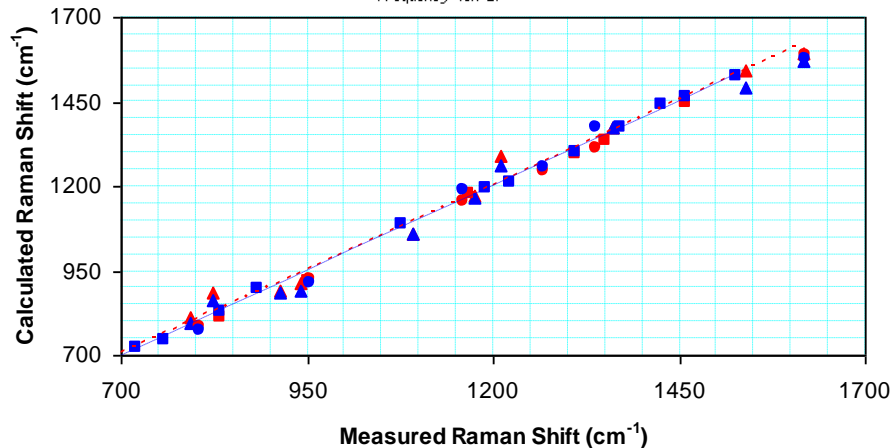
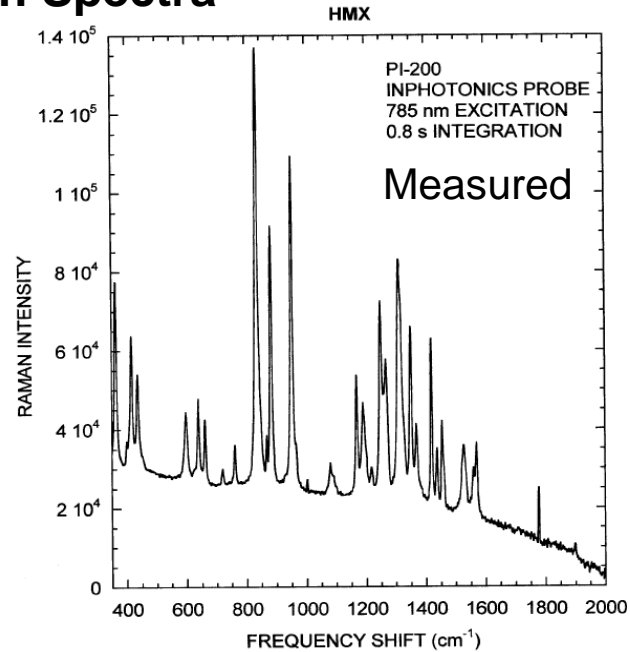
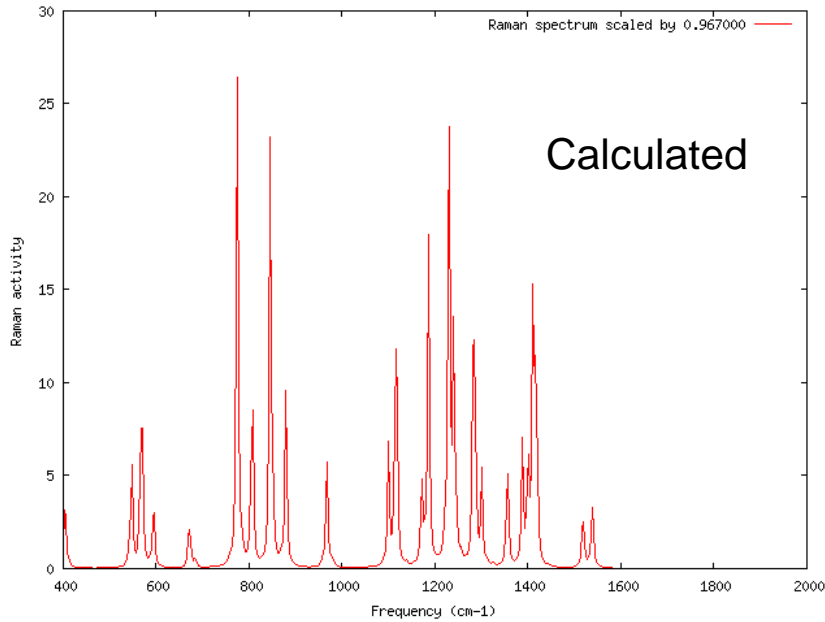
Demonstration

Drift of Analytes Through IMS Miniaturization of drift tube reduces separation

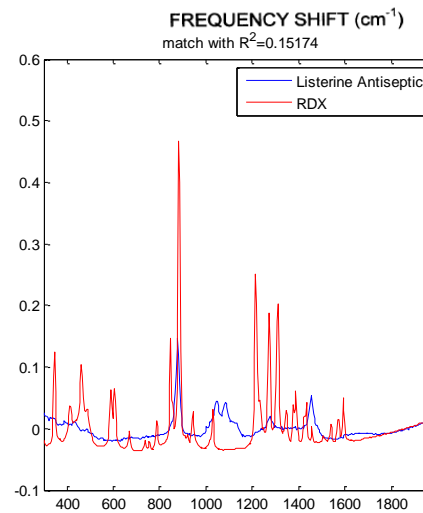


Demonstration (cont.)

Analysis of Raman Spectra



Good agreement to build Raman spectral library



Wide spectral range needed to reduce false alarms in Raman spectroscopy

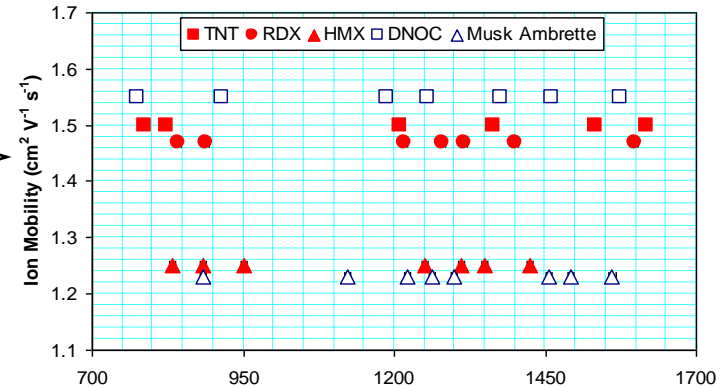
Courtesy of J. Barrow, FBI Academy

Future Plans

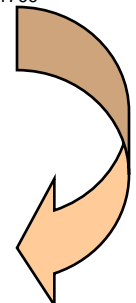
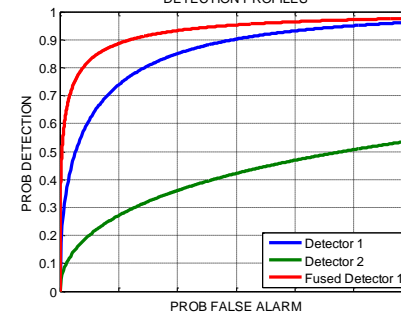
- Establish that IMS-Raman sensor reliably identifies unknown analytes in open environment

- Mission highlights

- Design and build IMS and surface enhanced Raman spectroscopy subcomponents; test and integrate them
- Test hybrid system
- Develop miniaturization protocol
- Collaboration with academe and government labs



Improved threat classification



Impacts

- Provides a rugged, miniaturized detection system for homeland security and defense, force protection, law enforcement, and public health
 - Immediately improves the performance of open environment trace explosives detectors
- Provide the technology basis to detect a broad-range of explosive threat substances
 - Rapidly (almost in real time, ~ seconds)
 - With high sensitivity (sub-picogram level) and specificity