Development of Eye-Safe Lidar Technology for Aerosol and Cloud Measurements

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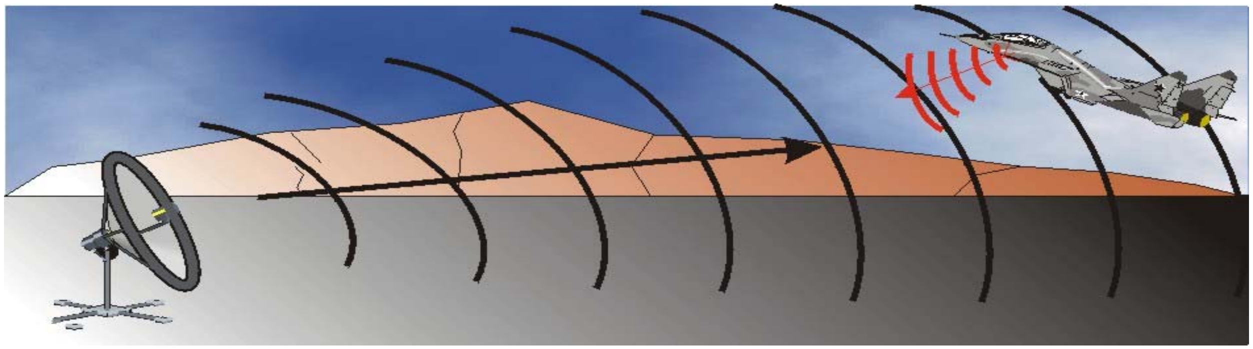
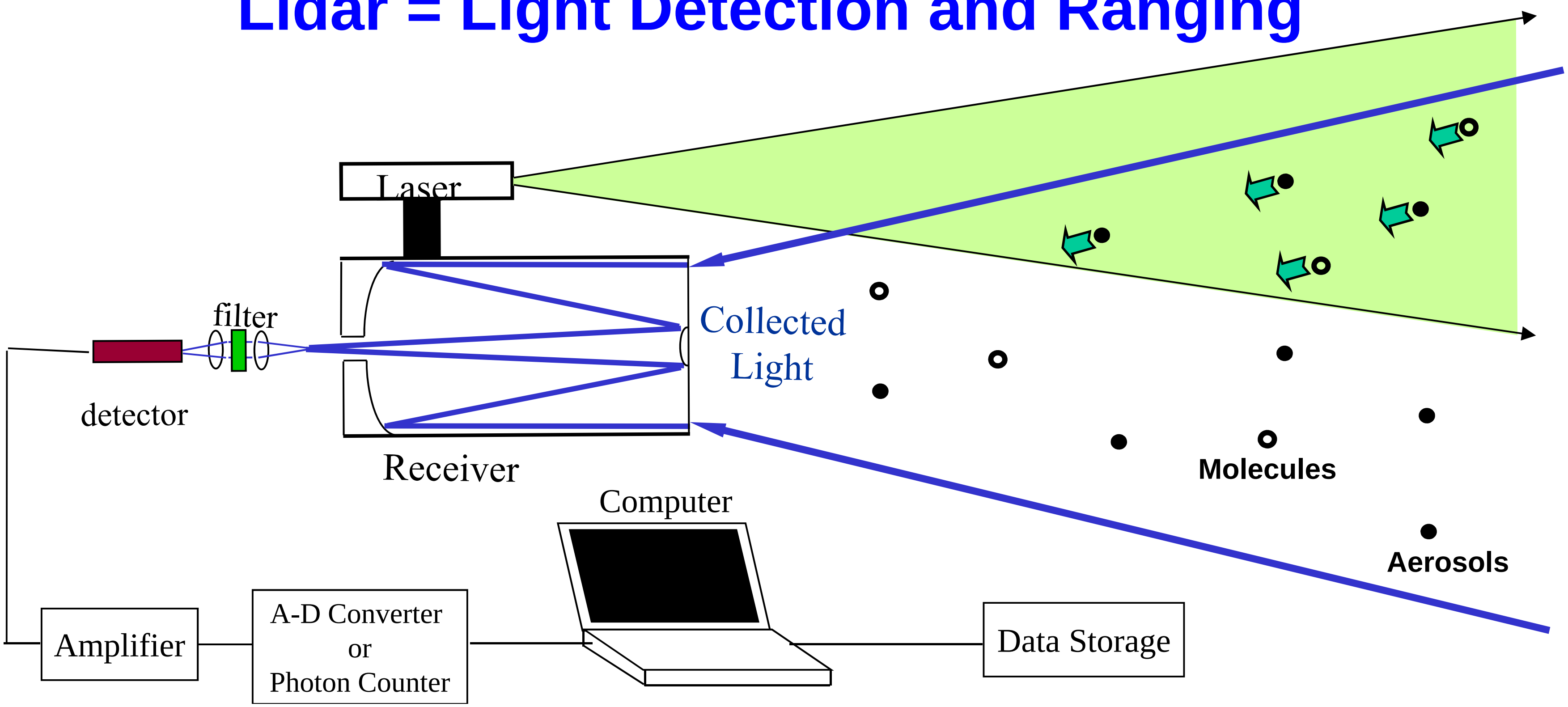
Presentation Outline

- **Lidar Overview**
- **Eye-Safe Lidar for Atmospheric Aerosols**
- **Differential Scattering Lidar for Bio-Agent Detection**
- **Laser Interrogation of Surface Agents (LISA)**

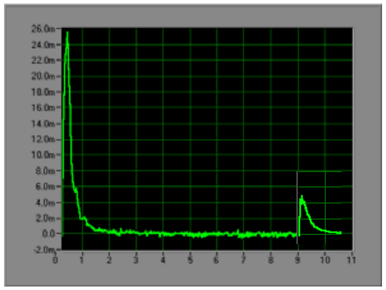
Radar = Radio Detection and Ranging

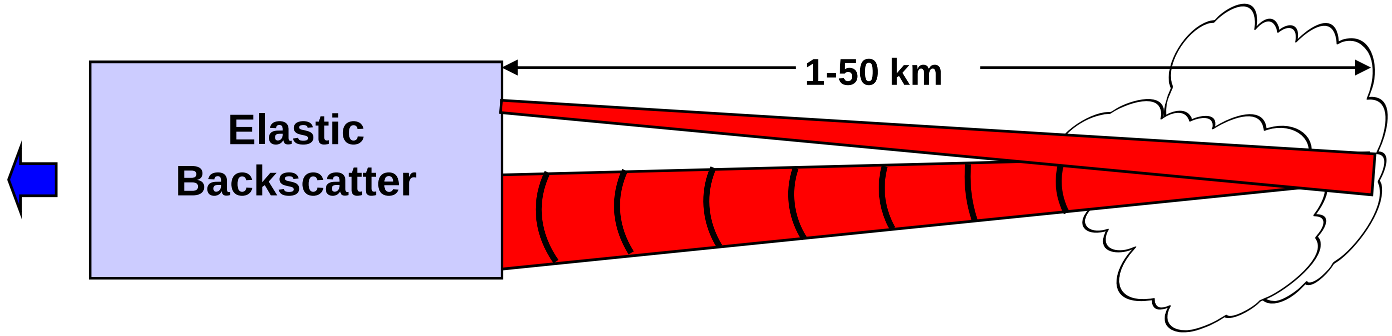


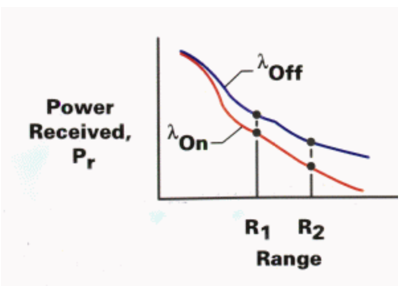
Lidar = Light Detection and Ranging

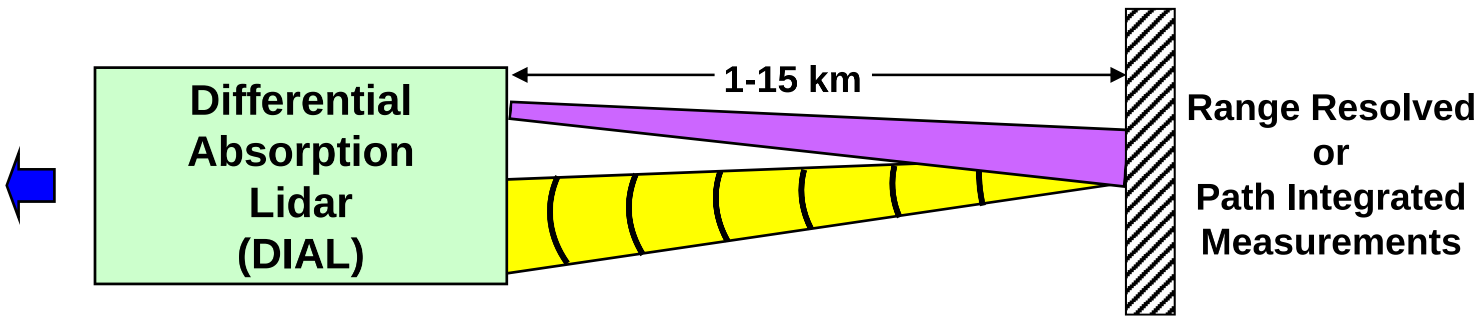


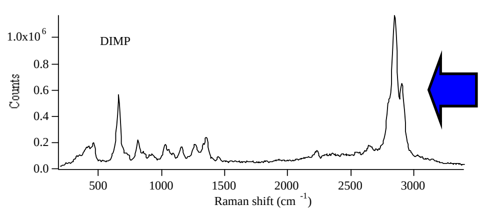
ITT Lidar Measurement Techniques

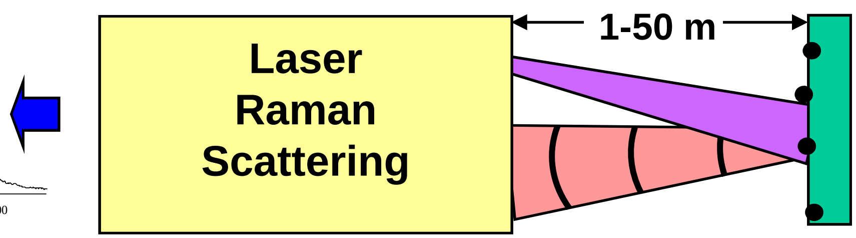








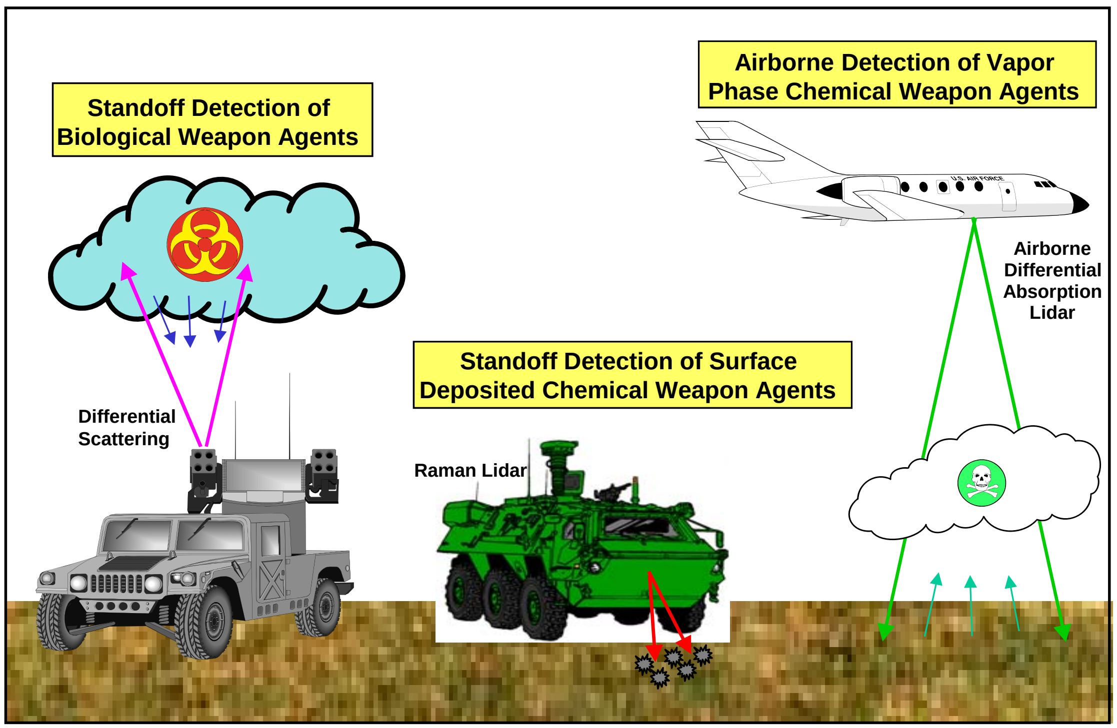




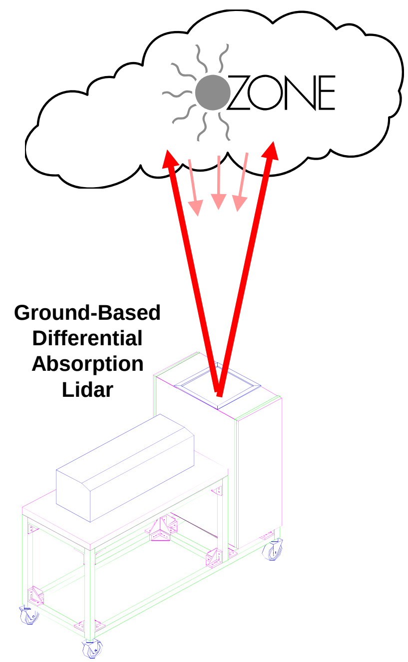
ITT Lidar Technology Program

The ITT lidar team develops and fields operational lidar sensors for chem/bio warfare agent detection and for atmospheric and environmental measurements.

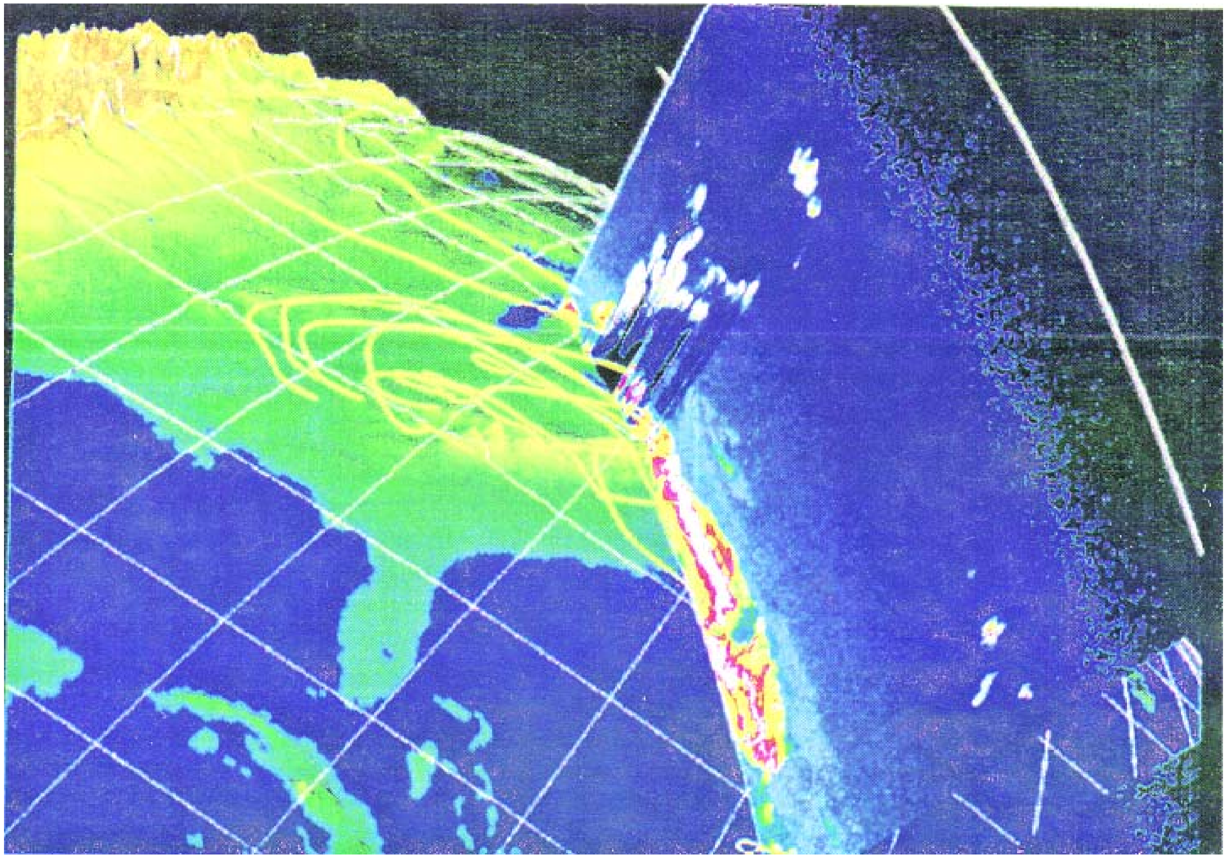
Chemical and Biological Agent Detection



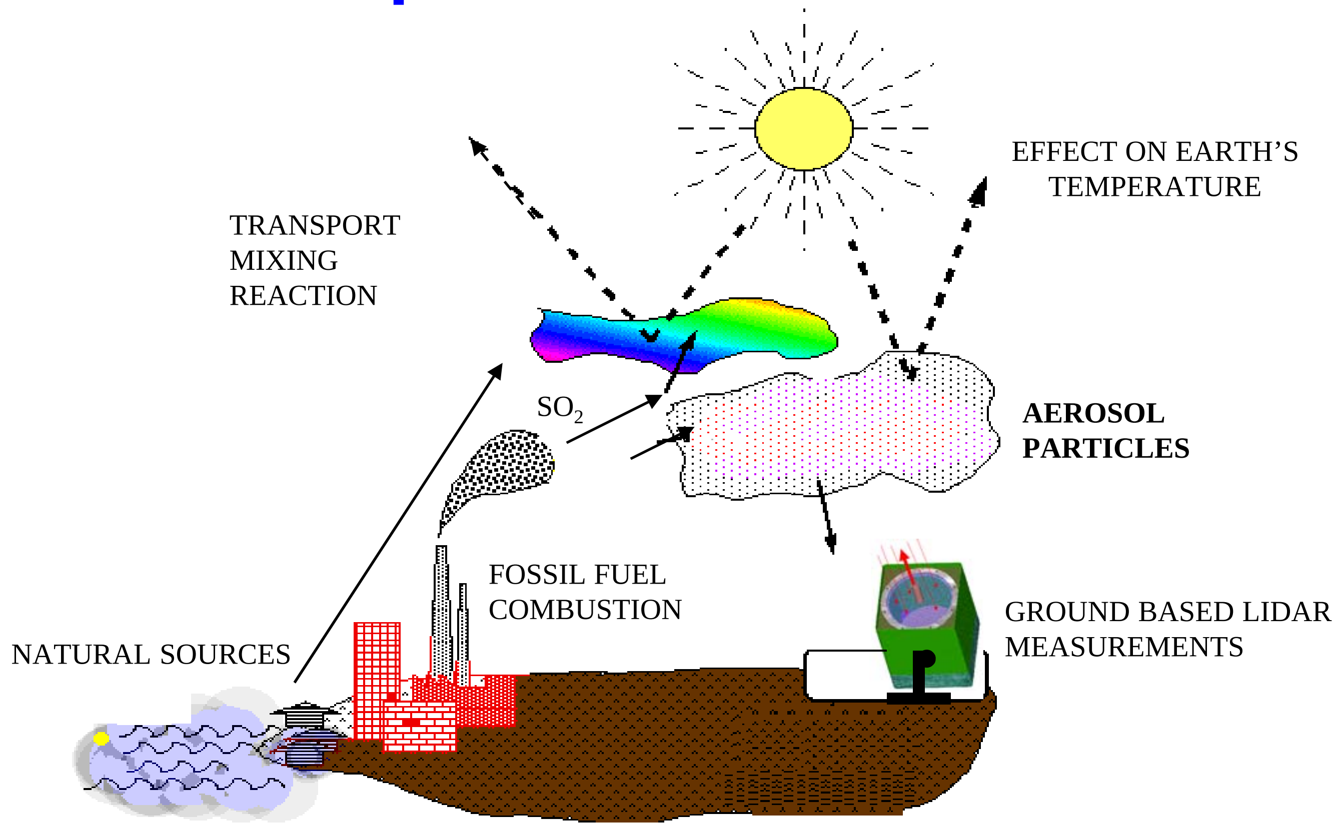
Atmospheric & Environmental Lidar Sensors



Eye-Safe Lidar for Atmospheric Aerosols



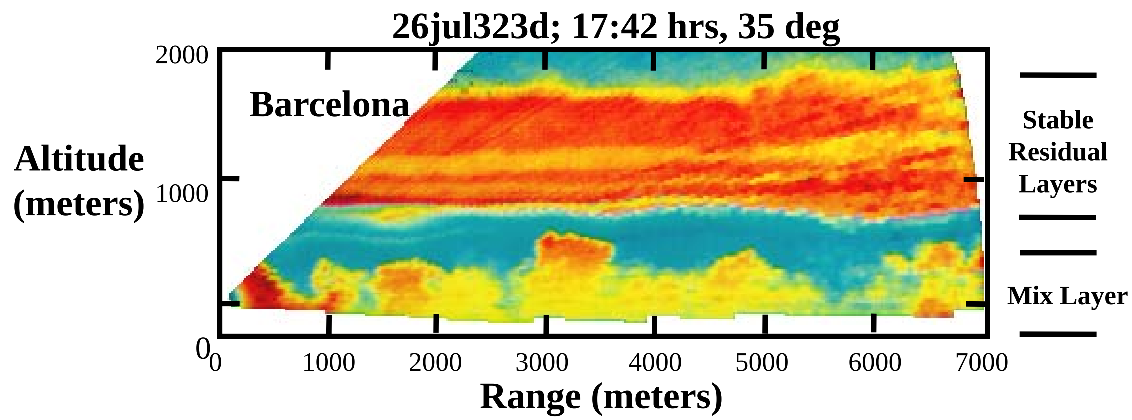
Atmospheric Aerosol Sources

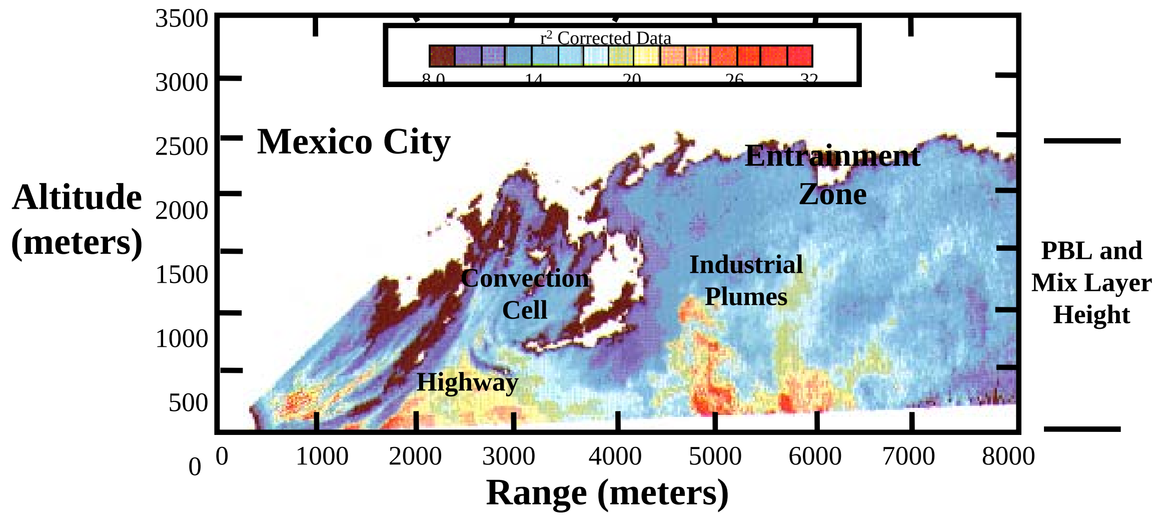


Natural Sources: windblown dust, sea spray, volcanoes, gas-to-particle conversion; etc.

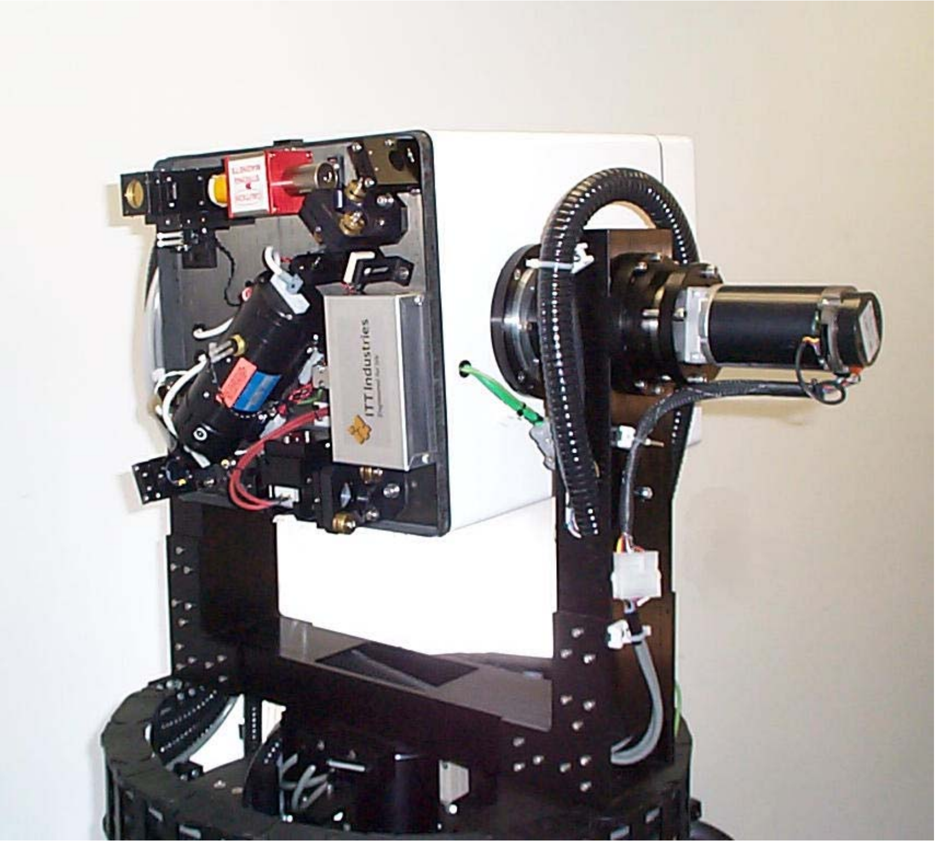
Anthropogenic Sources: fuel combustion, material processing (eg.crushing, grinding), intentional release of biological agent aerosols

Examples of Aerosol Lidar Measurements



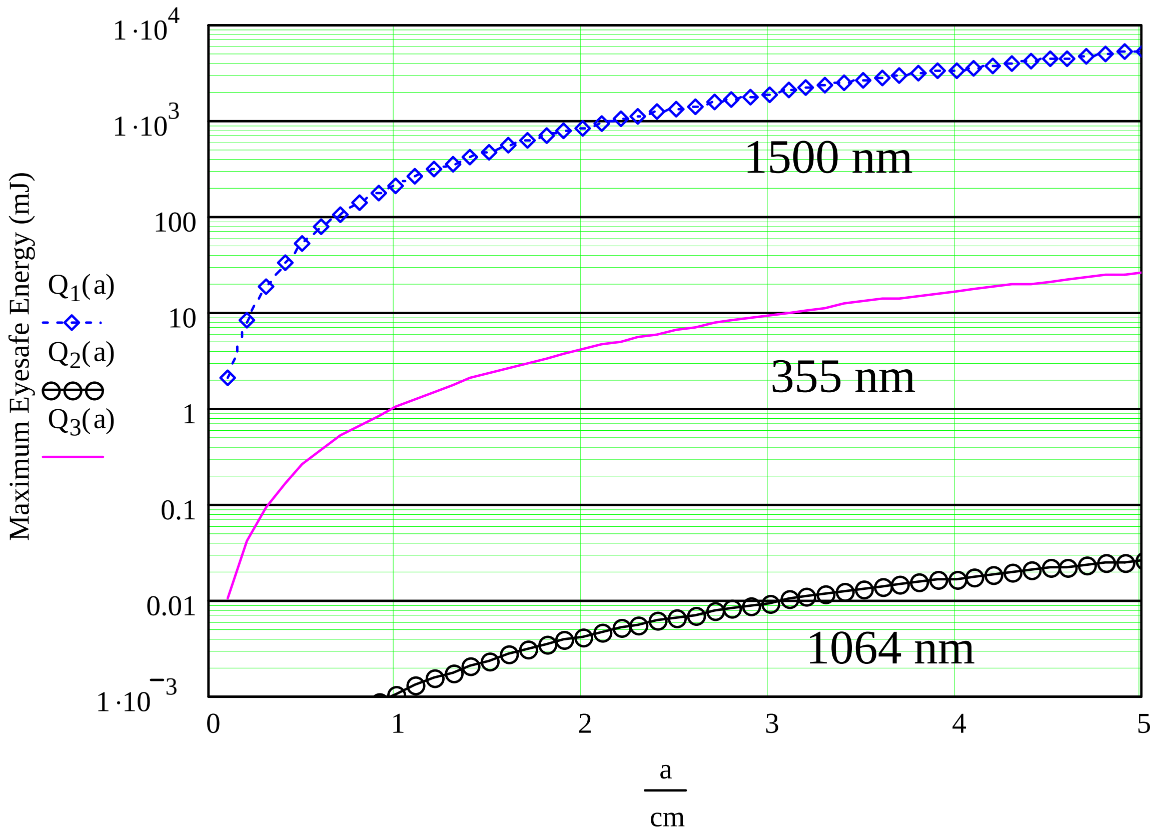


Hampton University Eye-safe Aerosol System



Eye Safety Considerations

Max Eyesafe Energy vs. Beam Diameter, a, at Laser Output



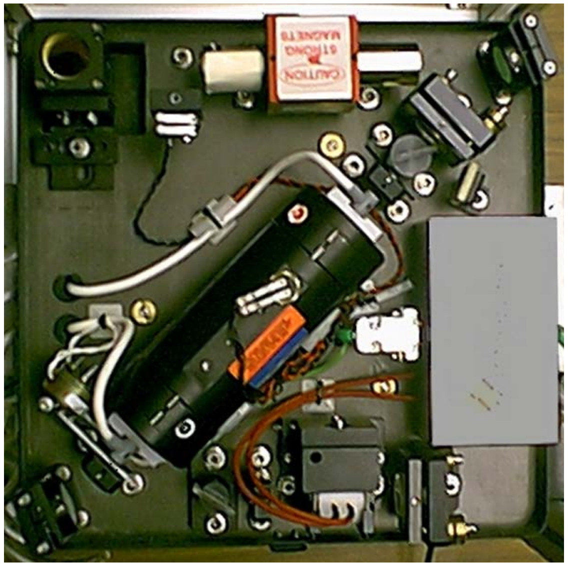
Beam diameter at laser output aperture

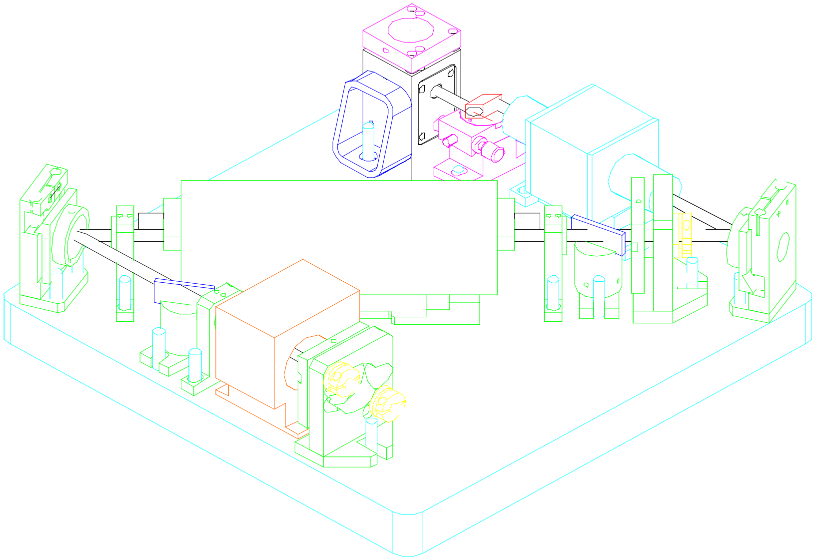
For the same operating parameters, a 1.5 μm laser is

~10^5 times safer than 1.064 μm laser

~200 times safer than 0.355 μm laser

Eye-Safe Near-IR Transmitter

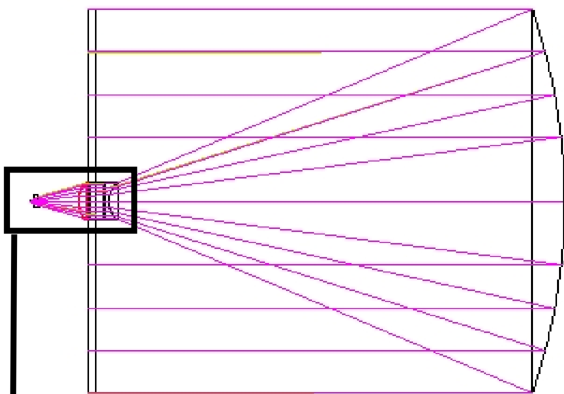




- **Operation at 20 Hz yielded unusually high divergence for Nd:YAG and OPO.**
- **Nd:YAG reconfigured for lower PRF operation.**
- **Present tests underway to fully characterize effects of pump divergence and PRF**

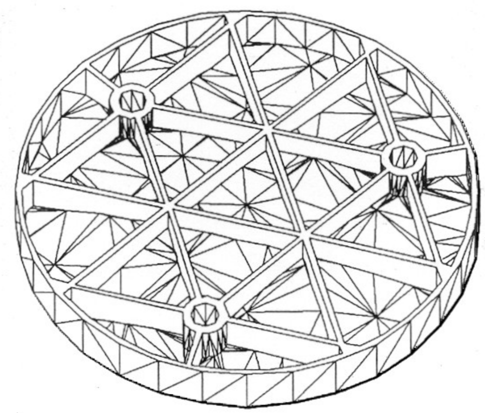
Nd:YAG Output (14 Hz)	320 mJ
After Isolator	290 mJ
OPO Output	82 mJ
OPO Energy Stability (σ/mean)	2%
Nd:YAG Divergence (Full Angle) M^2	0.43 x 0.80 mrad 3 x 6
OPO Divergence (Full Angle) M^2	4.8 x 5.8 mrad 12 x 23

Receiver Optics

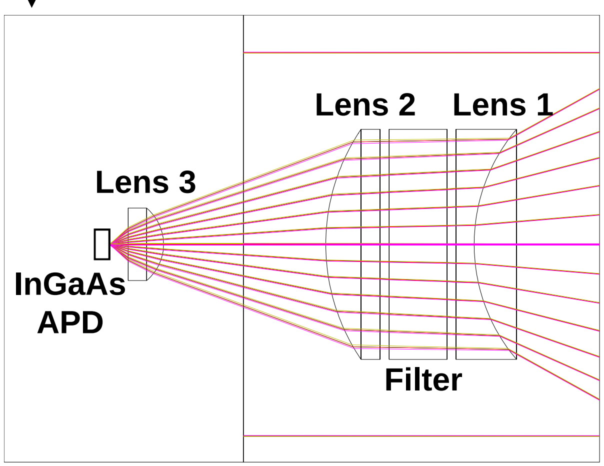


10" Catadioptric Telescope

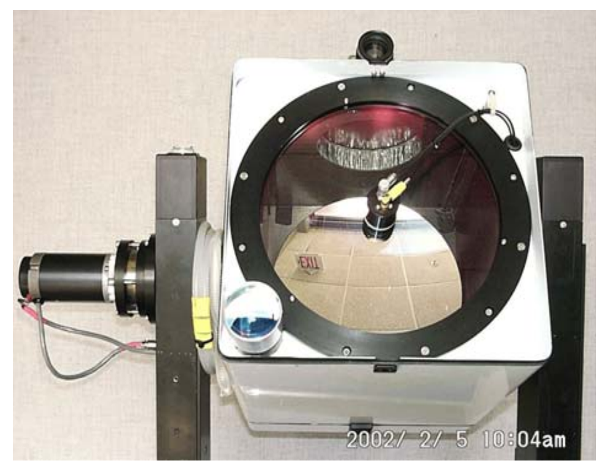
Receiver Optical Design



Lightweight Telescope Mirror



Lens/Filter Subassembly

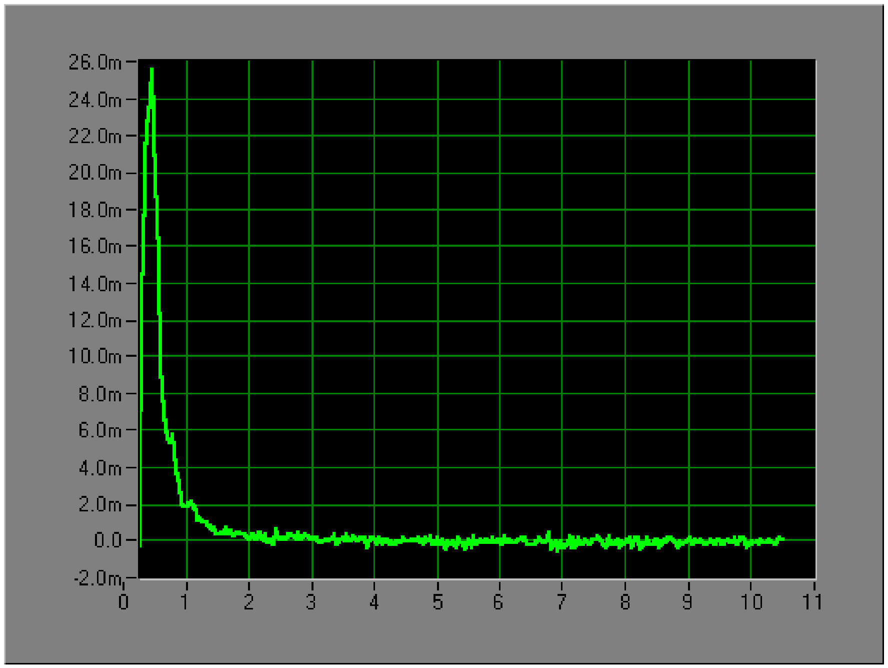


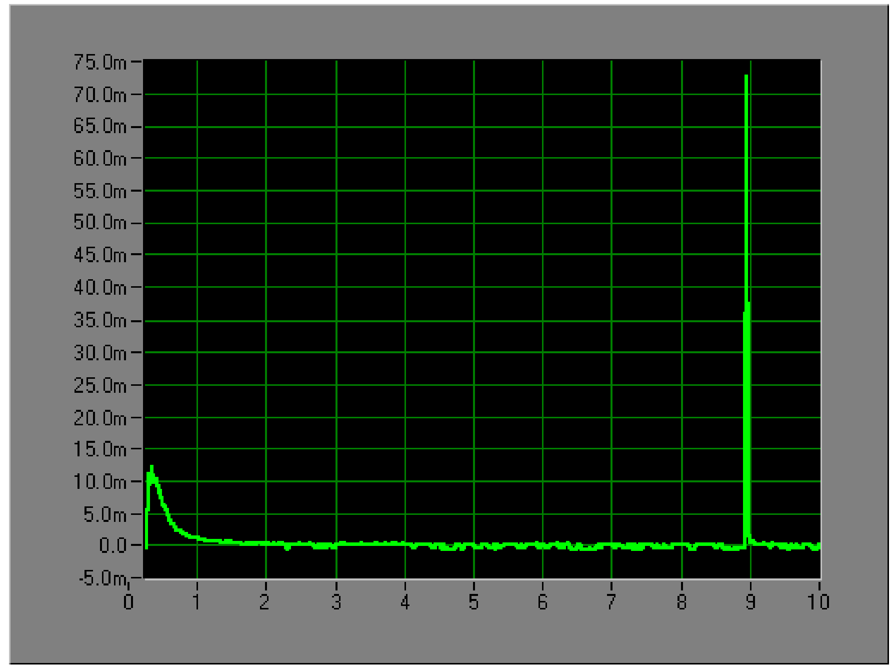
Transceiver Housing

CLASS Lidar Team at Hampton University

CLASS Center for Lidar and Atmospheric Sciences Students

Atmospheric and Hard Target Return Signals



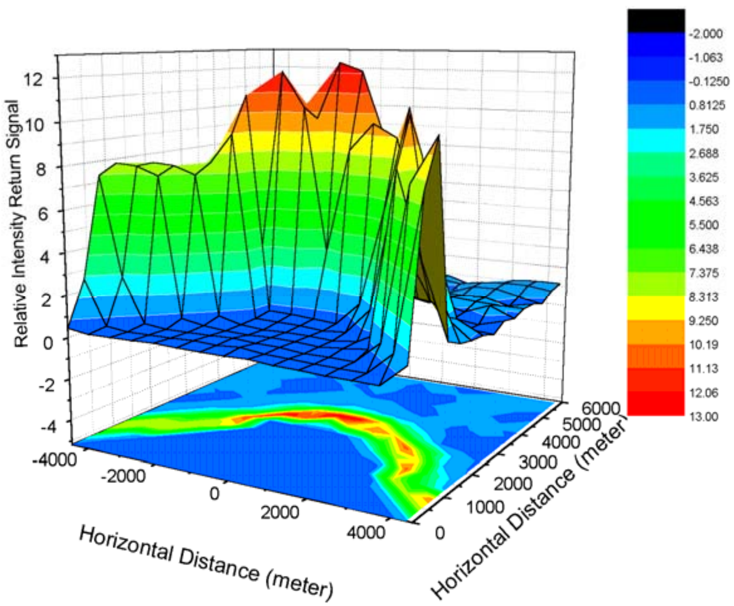


Near Field Return

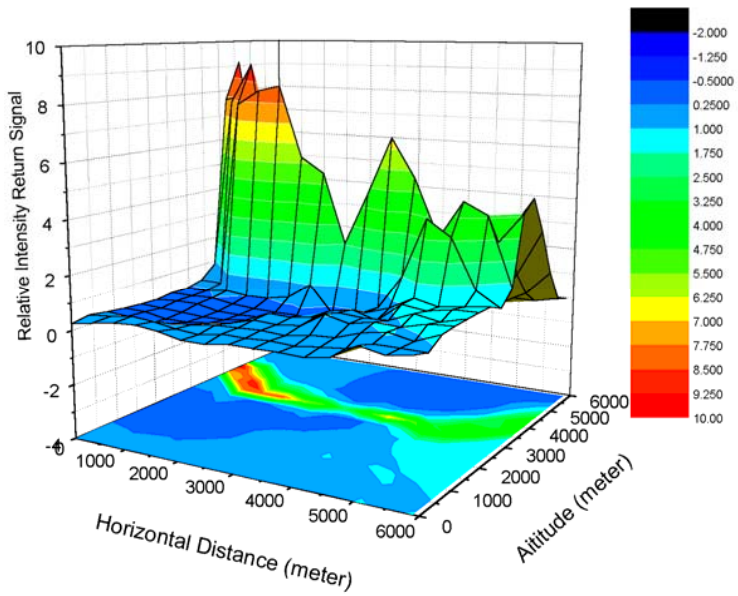
Far Field Return

(Sandia Mountains)

Cloud Measurements



(A)



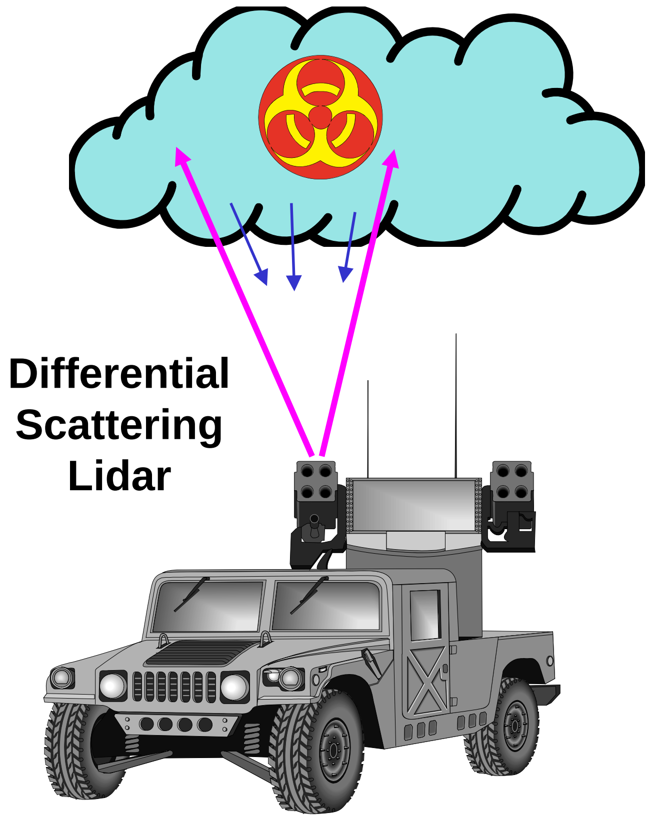
(B)

Scanning Lidar Backscatter Signal After Background Subtraction and Range Correction
(A) Jan-02-2002, Hampton, USA, azimuthal scanning of a cloud with 70 degrees elevation angle,
(B) Jan-02-2002, Hampton, USA, elevation scanning of a cloud

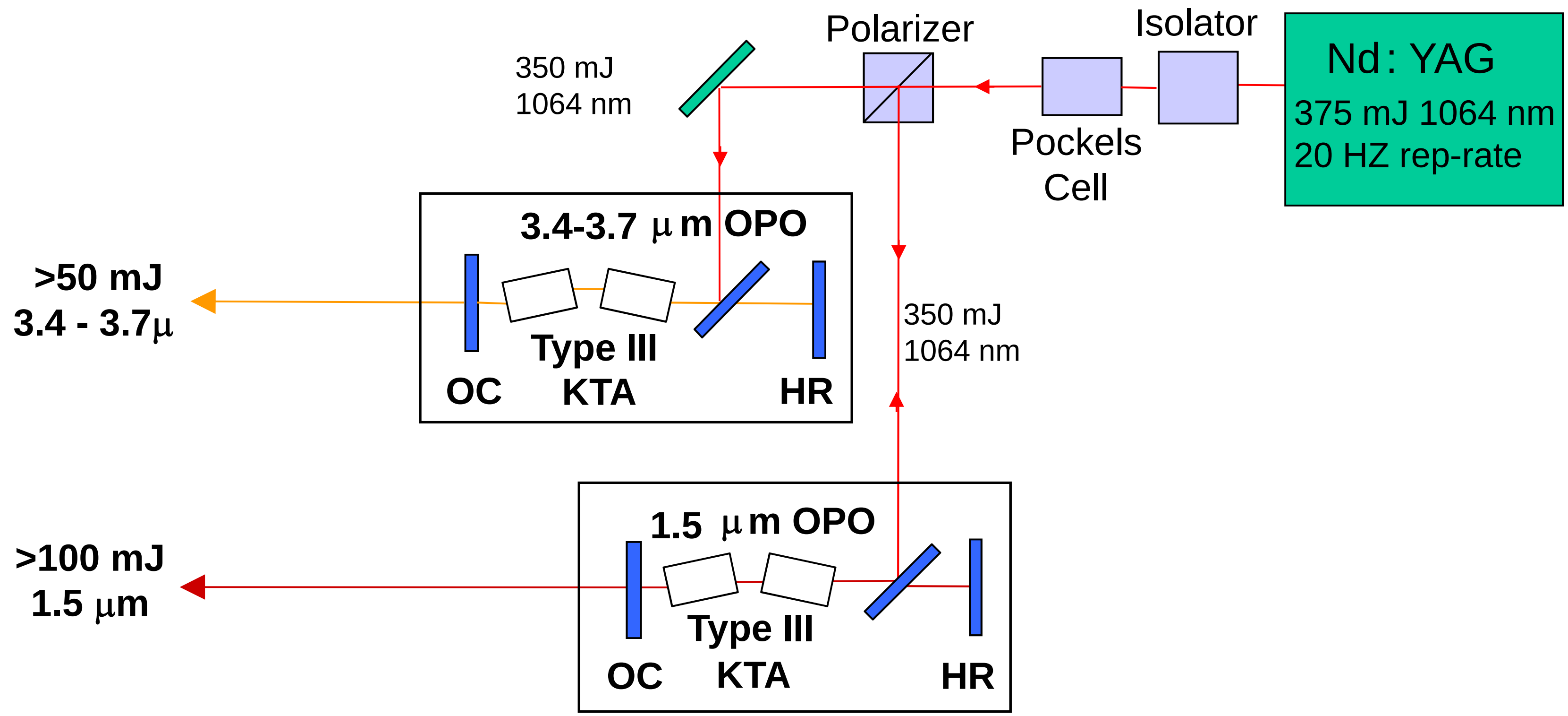
Micro-Pulse Lidar (MPL) Technology

- Pioneered by NASA Goddard Space Flight Center
- Uses high rep rate (1-10 kHz)/low pulse energy (10-50 μJ) at 532 nm to achieve eye-safe output at the aperture
- Low-cost, reliable, autonomous operation
- Requires long time averages and not conducive to scanning
- NASA GSFC is developing a network of these lidars (MPL-Net) at various locations around the world

Remote Detection of Bio-Agent Aerosols



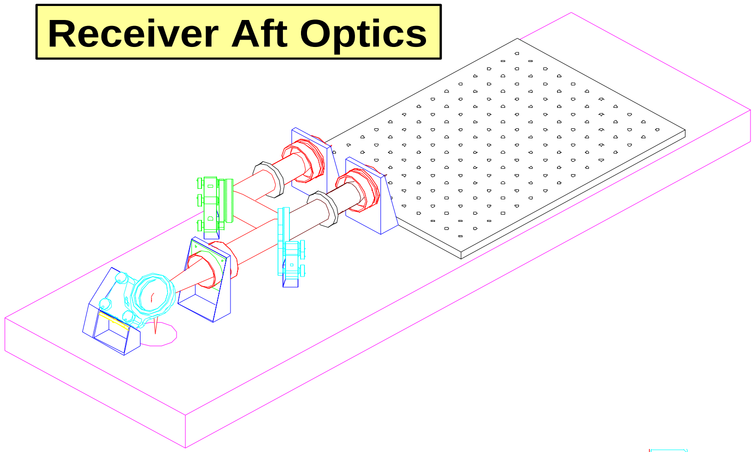
Transmitter for Bio-Agent Detection Using Differential Scattering Lidar

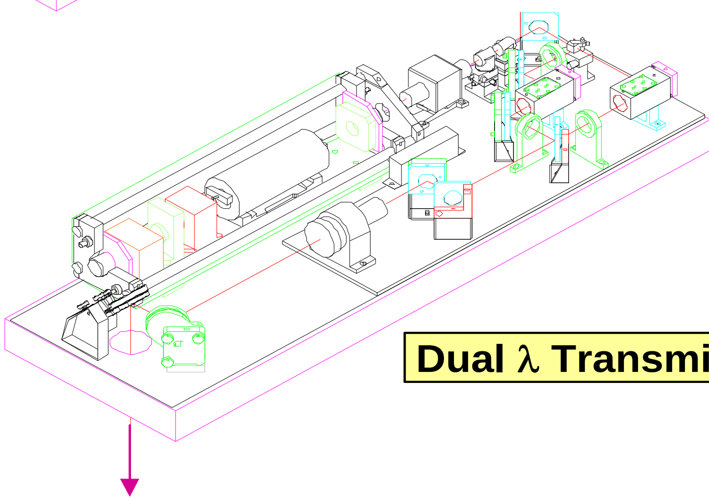


ITT is developing a DISC lidar system using this transmitter for the ARMY SBCCOM in collaboration with Physical Sciences, Inc.

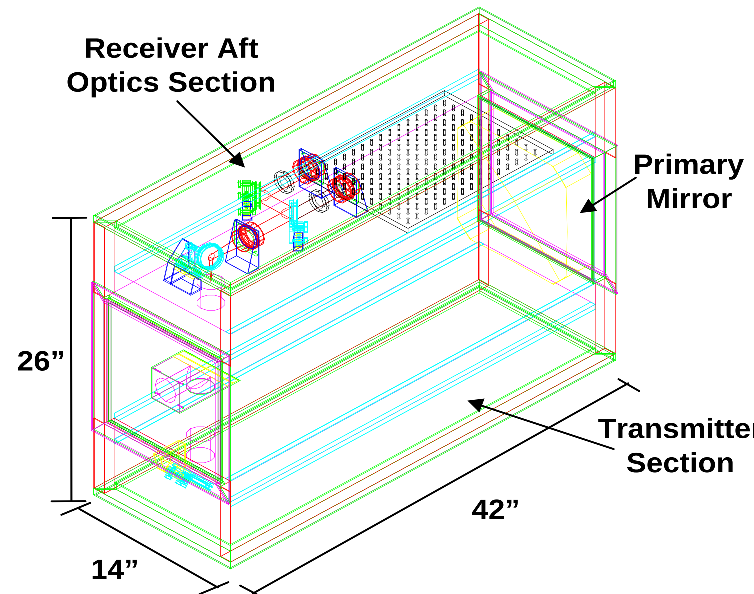
Bio-Agent Lidar System Transceiver Design

Receiver Aft Optics





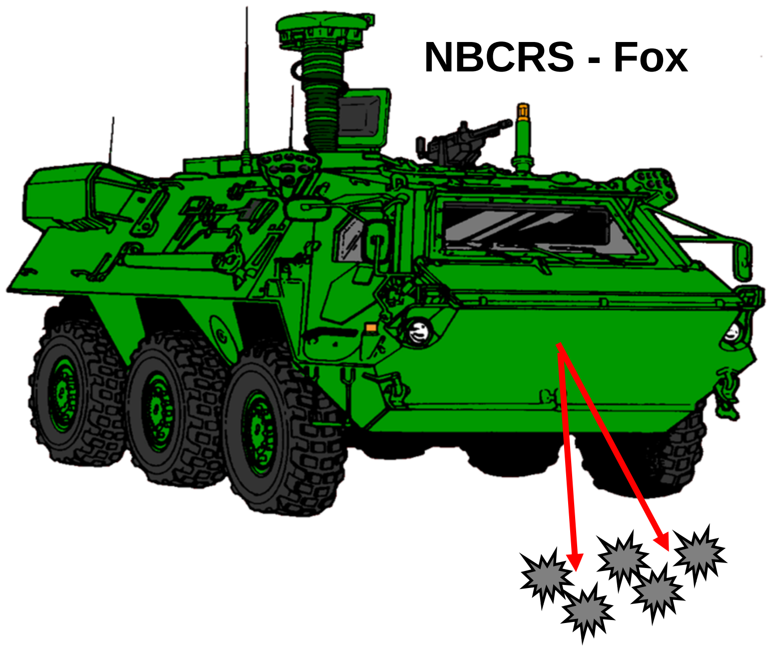
Dual λ Transmitter



Transceiver Module

Bio-Agent Lidar System

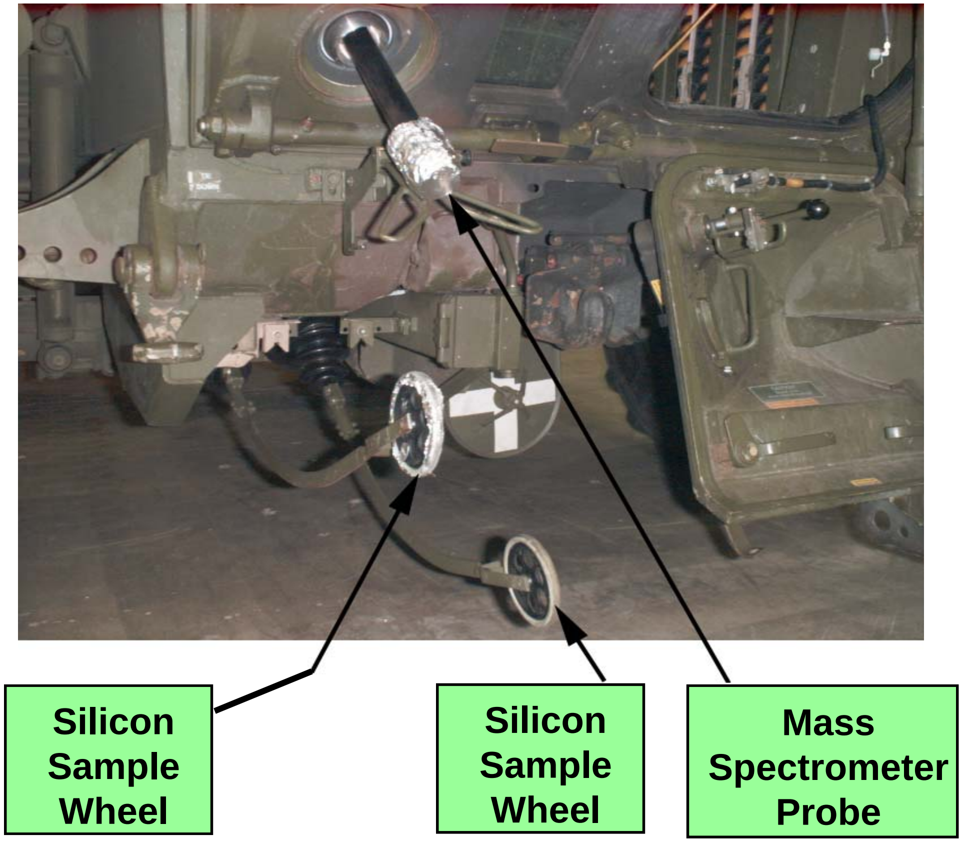
Laser Interrogation of Surface Agents (LISA)



Current Approach for Ground Contamination

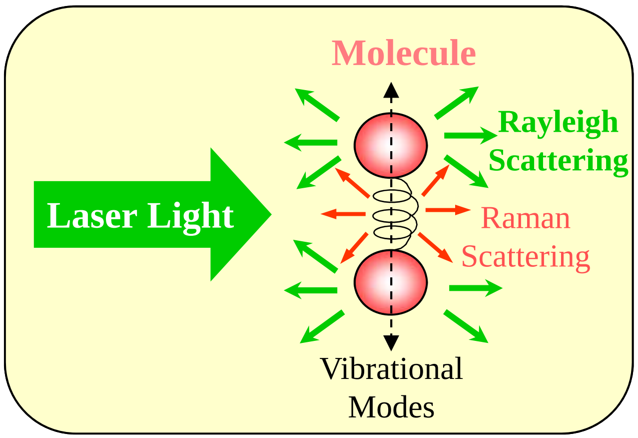
NBCRS Fox Vehicle

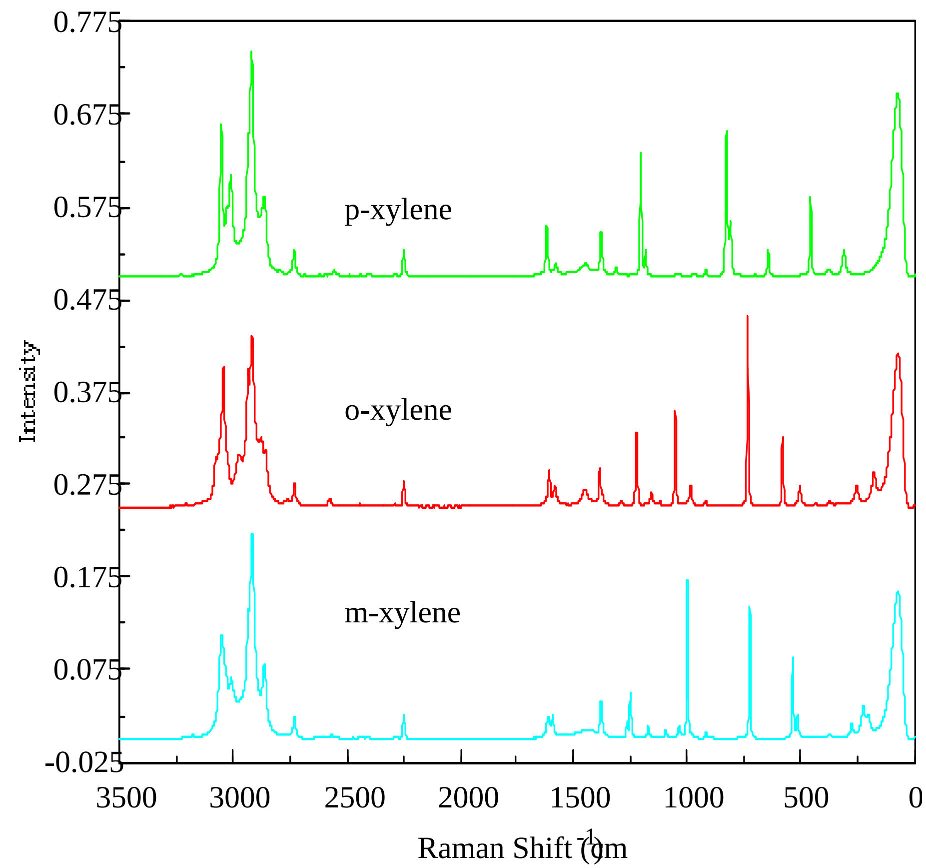
Sample Wheel Device



- Requires sample collection using a surface-contact mechanical device
- Requires a dedicated device operator
- Slow response and very small sampling area
- Operational and supply logistics issues

Measurement Methodology: Raman Scattering

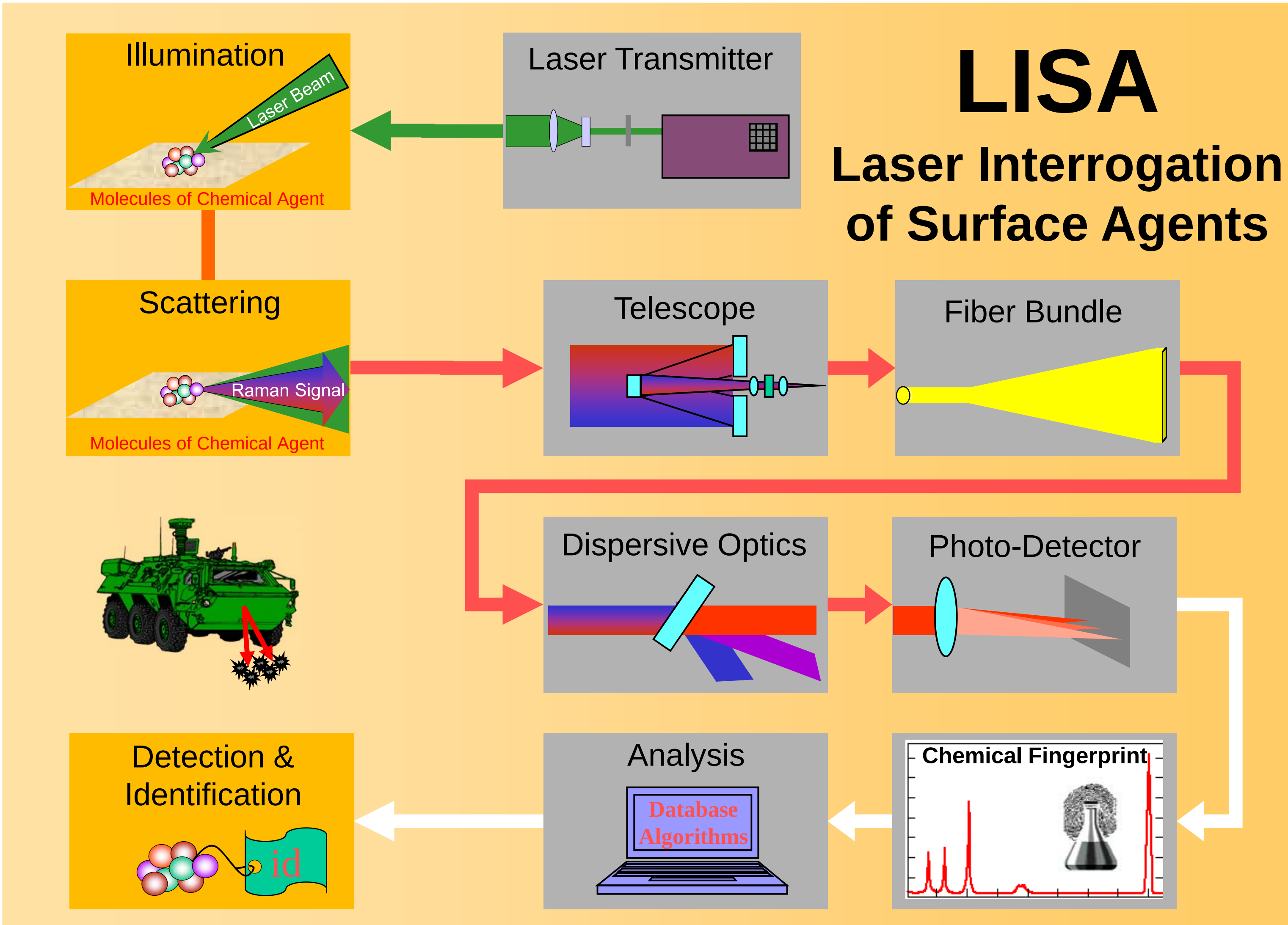




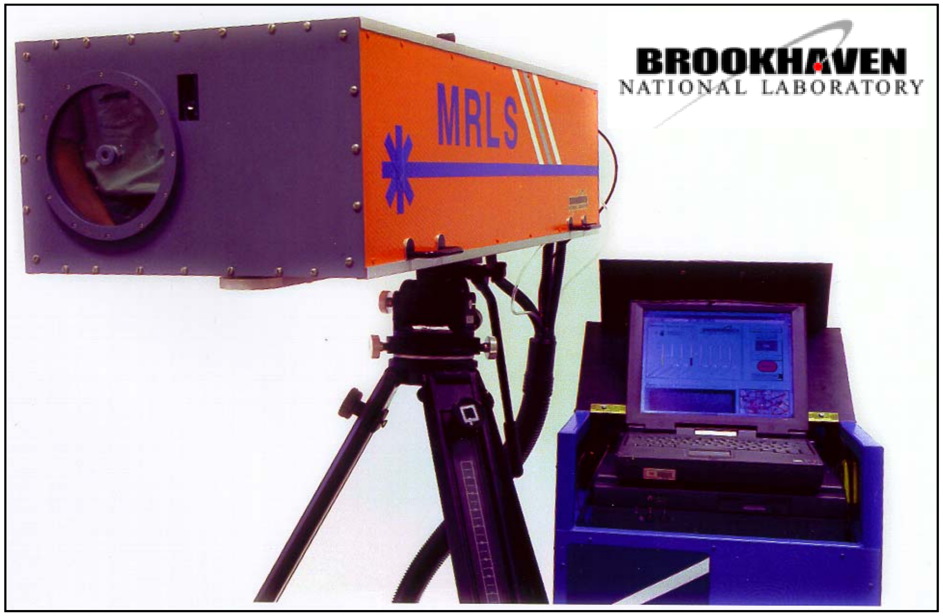
- **Vibrational Raman Scattering occurs when light interacts with a molecule**
- **A small amount of wavelength-shifted light is scattered**
- **Amount/intensity depends on the molecule's size, shape, and strength (vibrational modes of the molecule)**
- **Creates a distinct "spectral fingerprint"**

Selectivity is the hallmark of Raman spectroscopy

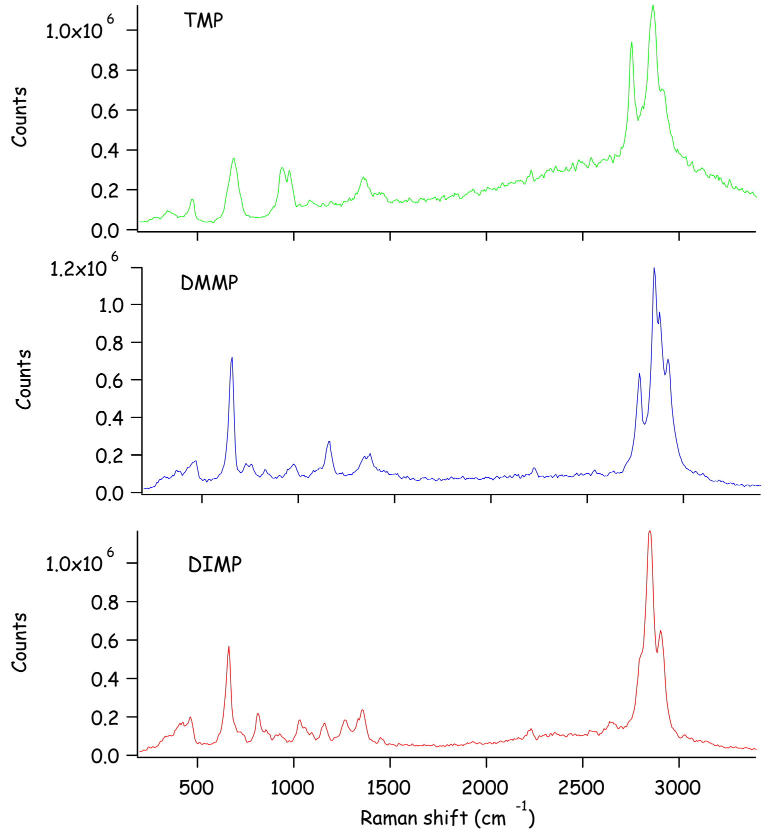
LISA Concept



LISA Proof-of-Concept: MRLS



BNL Mini-Raman Lidar System (MRLS) uses laboratory off-the-shelf components

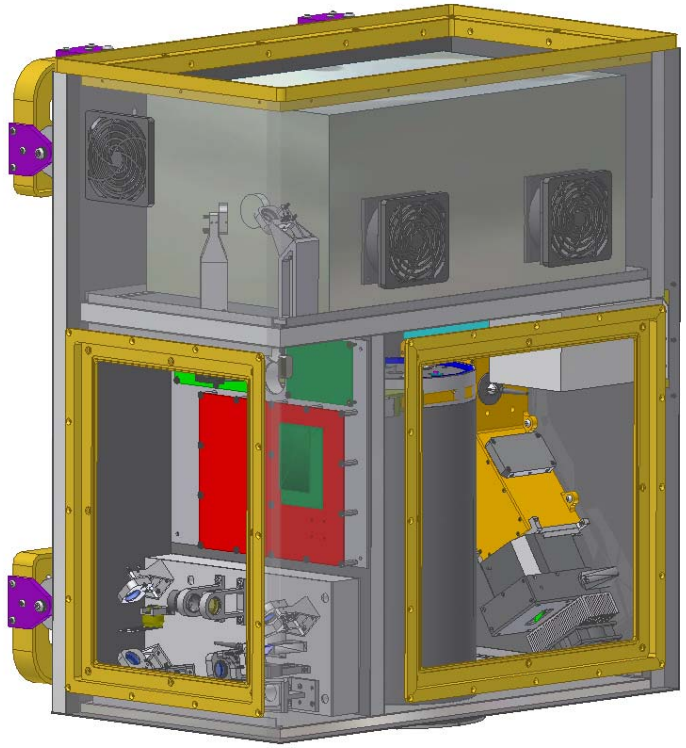


MRLS measured spectral signatures & distinguished related compounds

MRLS Sensitivity ➡ 2 g/m^2 (single shot at 1 m)

Military requirement ➡ 0.5 g/m^2

ITT LISA-Recon System

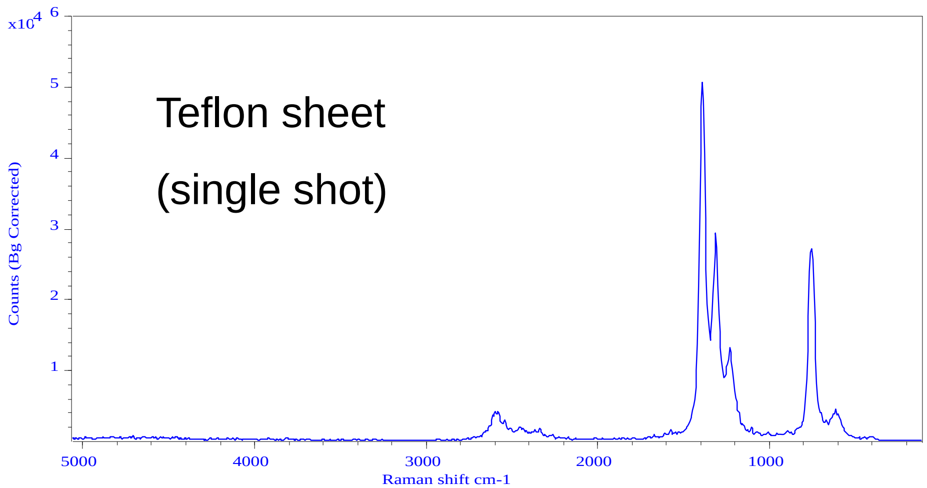


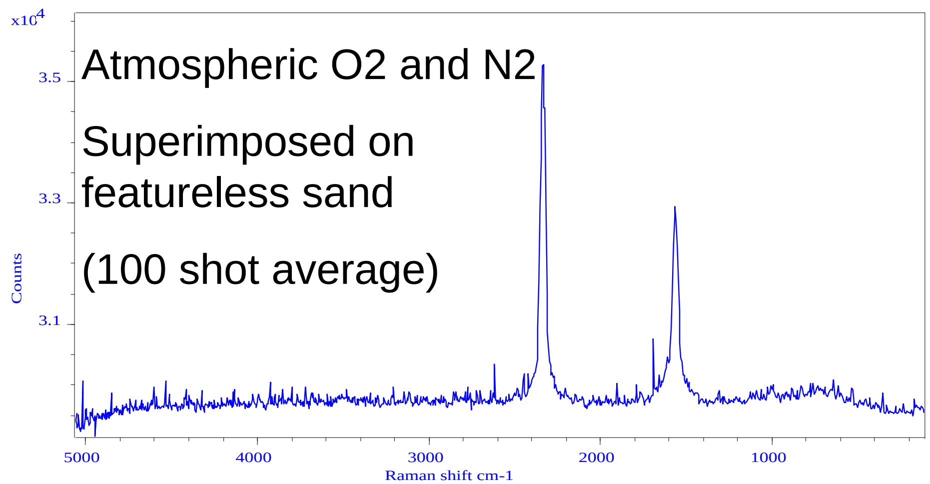
Preparation for Field Measurements

HMMWV Test Vehicle

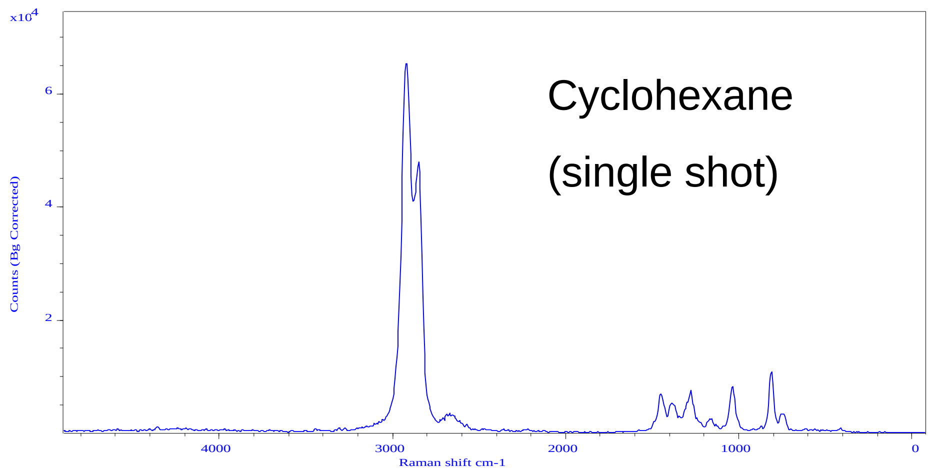
Sensor Module & Vibration Mount

Single Shot Measurements & Identification

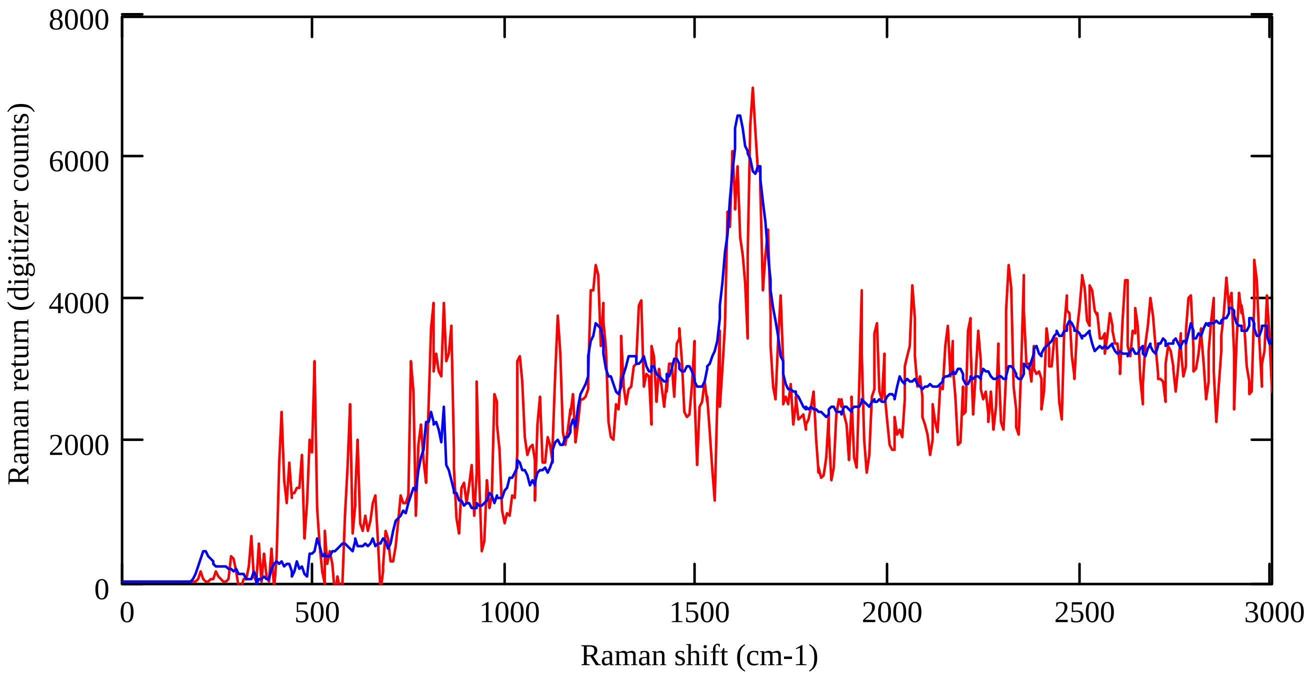




- Cyclohexane and Teflon are materials used by BNL to characterize their system.
- We can use them to compare our system performance to the baseline BNL system
- The O2 & N2 signature forms the kernel of an instrument confidence check



Initial Single Shot Measurements of a Chemical Agent Simulant



- **Red curve**: single shot measurement of MeS at 0.25 g/m^2 with 9.1 mJ laser pulse.
  - Spectra for the atmosphere, water and the quartz vial (2 mm path length) are removed.
  - SNR of the MeS peak near 1610 cm^{-1} is approximately 15.
- **Blue curve**: same but 100 shot average, 15 mJ pulse.

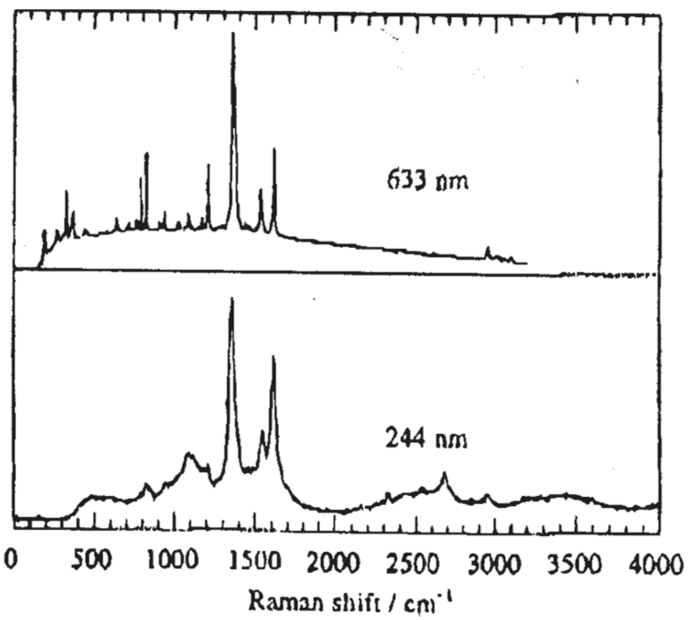
ESTCP Project

Application of (LISA) Technology to DoD Environmental Site Characterization Requirements

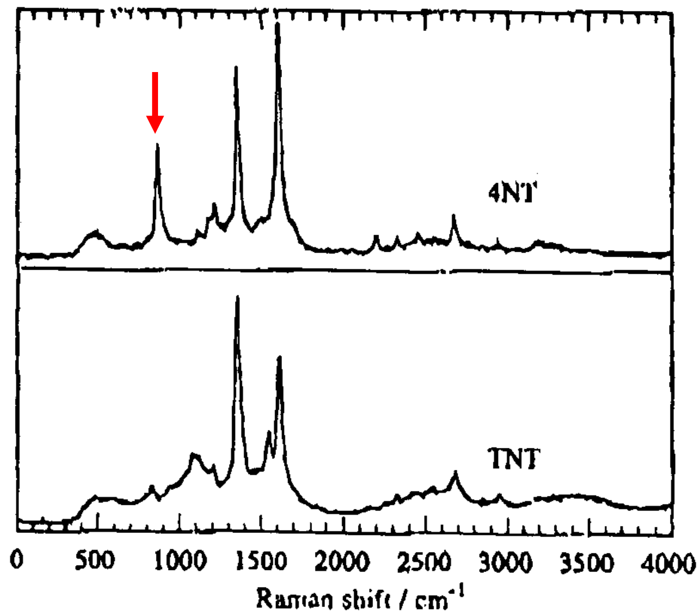
Dr. Steve Christesen – Army ECBC
Mr. Scott Higdon – ITT Industries
Dr. Arthur Sedlacek – BNL
Ms. Tamera Rush - AEC
Dr. Daniel Powell – EPA (Advisor)

Develop innovative, rapid screening technologies to detect and delineate land areas with soils containing contaminants associated with live fire training activities including energetic compounds (RDX, HMX, TNT, DNT), propellants, and their byproducts.

UV Detection of Explosives



TNT data showing the advantages of UV (< 253 nm) excitation



Raman spectra of TNT and 4NT can be distinguished by the strong peak at 860 cm^{-1}

UV excitation provides:

1. **Reduced fluorescence**
2. **Potential for simplified spectra and Raman scattering enhancement (10^3 to 10^6) from resonance Raman effect**

Data from Lacey, et al., Characterization and Identification of Contraband Using UV Resonant Raman Spectroscopy, SPIE Vol. 2937, 100 – 104, 1997.

LISA Future Missions

Mission Applications

- Reconnaissance vehicles
- Cargo inspection
- Shipboard sensor
- Homeland Defense
- Environmental cleanup
- Planetary exploration

Potential Users

- Army SBCCOM
- FAA/TSA
- Navy
- Civil Support Teams
- EPA
- NASA

LISA technology provides a unique solution to the very challenging problem of detecting and identifying surface-deposited chemicals