Planetary Surfaces and Atmosphere Characterization Using Combined Raman, Fluorescence, and Lidar Instrument from Rovers and Landers

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Introduction

NASA Langley Research Center (LaRC) initiated the development of the miniature Raman-Fluorescence spectrograph and Lidar system with Langley investment funds. Later, a proposal called "Combined Raman, Fluorescence, and Lidar Multi-Sensor (RFLMS) Instrument Development Program" under NASA Mars Instrument Development Project (MIDP) was jointly proposed by University of Hawaii and NASA LaRC in 2008 and was selected for funding. Finally, Raman, Fluorescence, and Lidar prototype instrument has been integrated onto a rover system and demonstrated at NASA LaRC. Surface and atmospheric characterizations are performed with this prototype instrument from a robotic platform to investigate and identify the water, ice, and dry-ice at a 15 meter distance as well as conducting atmospheric aerosol and cloud distributions profiling. Recently acquired Raman spectra from water, ice, and dry-ice as well as atmospheric characterization results [refs. 1-2] are discussed in this study. The objective of this study is to develop a remote Raman-Fluorescence spectroscopy and Lidar multi-sensor instrument capable for investigation and identification of minerals, organics, and biogenic materials as well as conducting atmospheric studies of Mars, Moon, Asteroids/Comets, Europa, Titan, Venus, and other planets from rovers and landers.

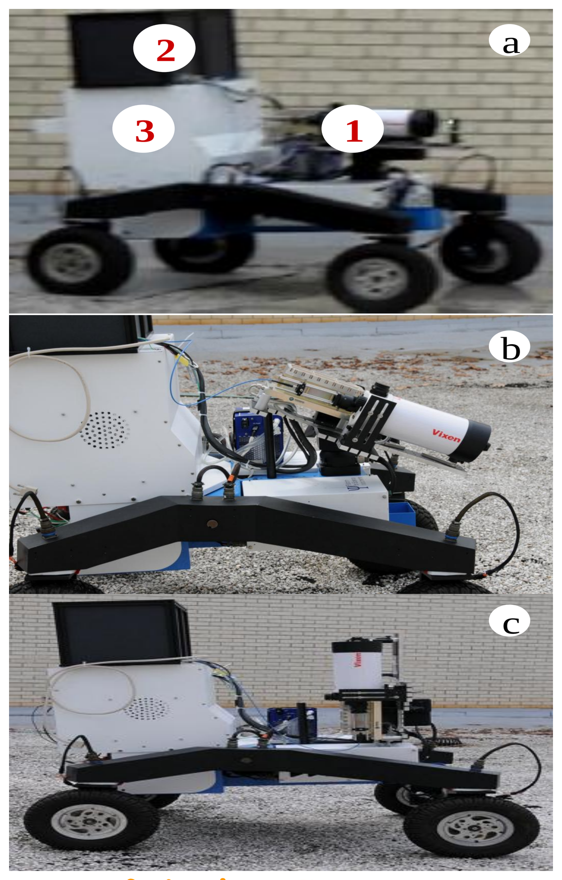
Approach

- The remote Raman spectroscopy and lidar instrument will be based on inelastic (Raman) and elastic (Mie-Rayleigh) light scattering
- This instrument will monitor atmospheric aerosol and cloud distributions by operating the instrument in the lidar mode at 532 nm
- This integrated remote instrument will be operated from a robotic platform and will perform Raman spectroscopy out to >60 m on the surface features and demonstrate long-range (to >10-km) atmospheric profiling capability

Remote Raman-Fluorescence & Elastic Lidar Instrument

Part 1: Transmitter and Receiver Module
Part 2: Sensor Module
Part 3: Data Acquisition and Power Conditioning Systems.

Mounted Part 1 on the left arm of the rover system and Parts 2 and 3 on the back of the rover system as shown in photo 'a'. This prototype instrument is suitable for multi-platform applications for remote sensing of surface reflected signal in photo 'b' and upward/horizontal-looking for atmospheric return signal in photo 'c' from a rover system.



Compact Remote Raman-Fluorescence & Lidar Instrument Key Components

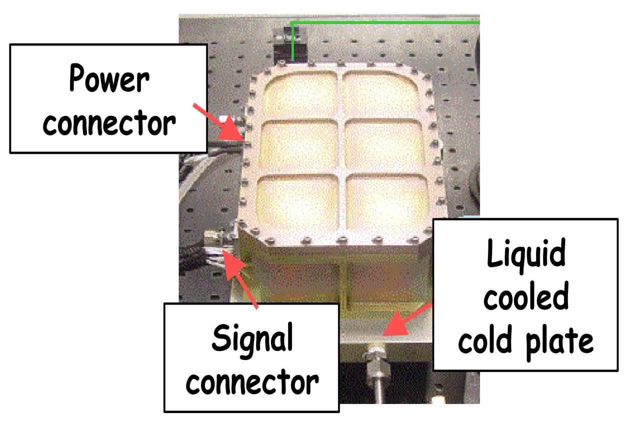
Transmitter

Nd:YAG laser from Fibertek (3-wavelengths: 355-,532-, and 1064-nm, total laser energy: 45mJ with repetition rate of 20 Hz)

Rceiver System Components

- Telescope (4" Diameter)
- Mini ICCD camera
- Photomultiplier Tube (PMT)
- Optical components (focusing lenses,beam expander, super notch filters,dichroic beam splitter, prisms)
- Compact spectrometer

Assembled laser

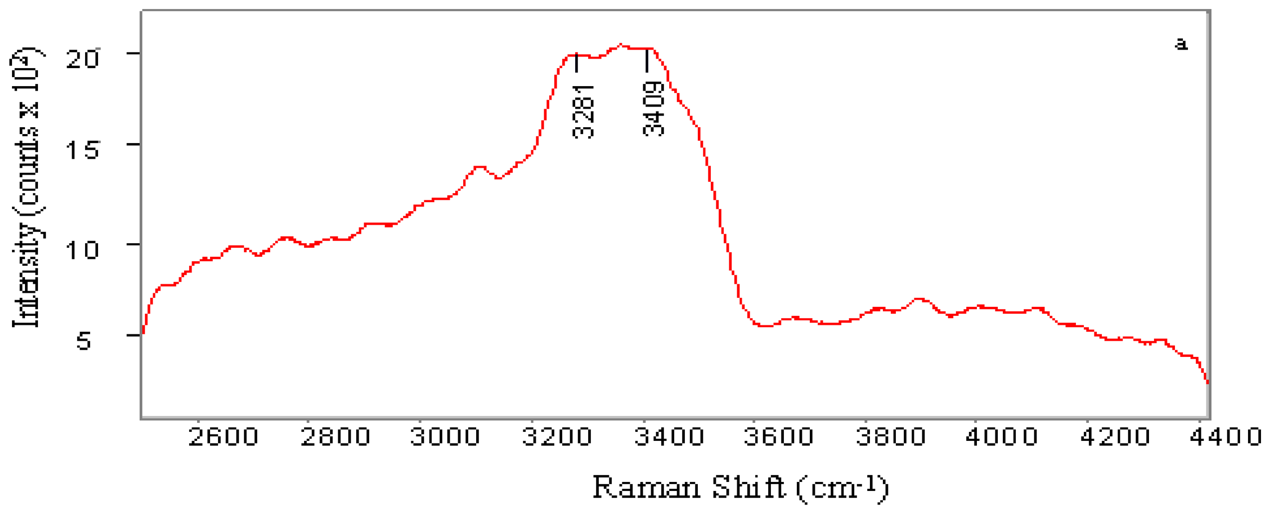


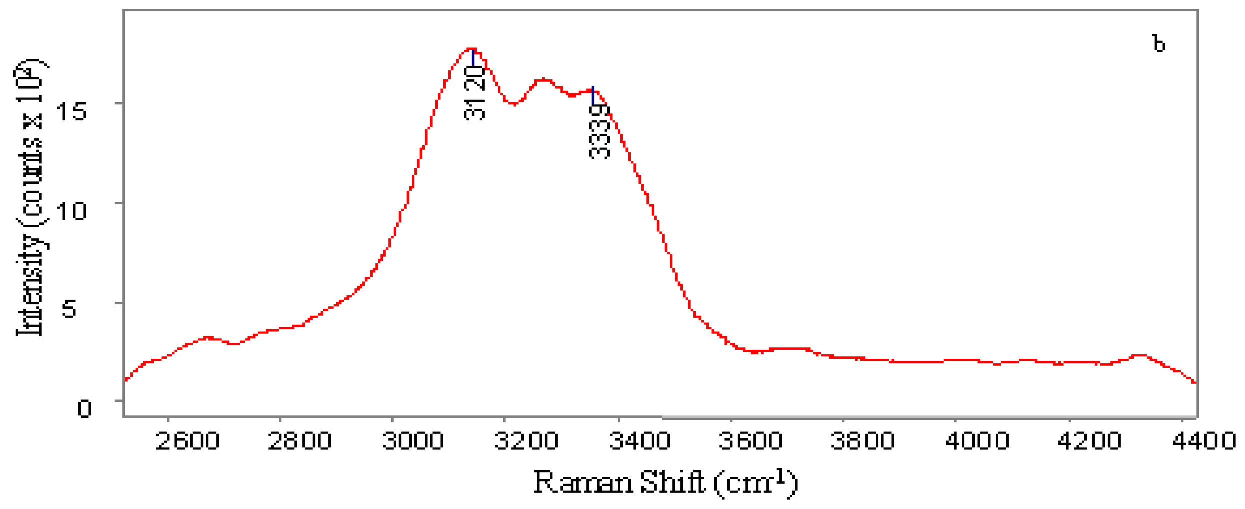
Dimensions: 20.3 cm x 12.3 cm x 6.3 cm
Volume: 1596 cm³; Mass: 2.09 kg

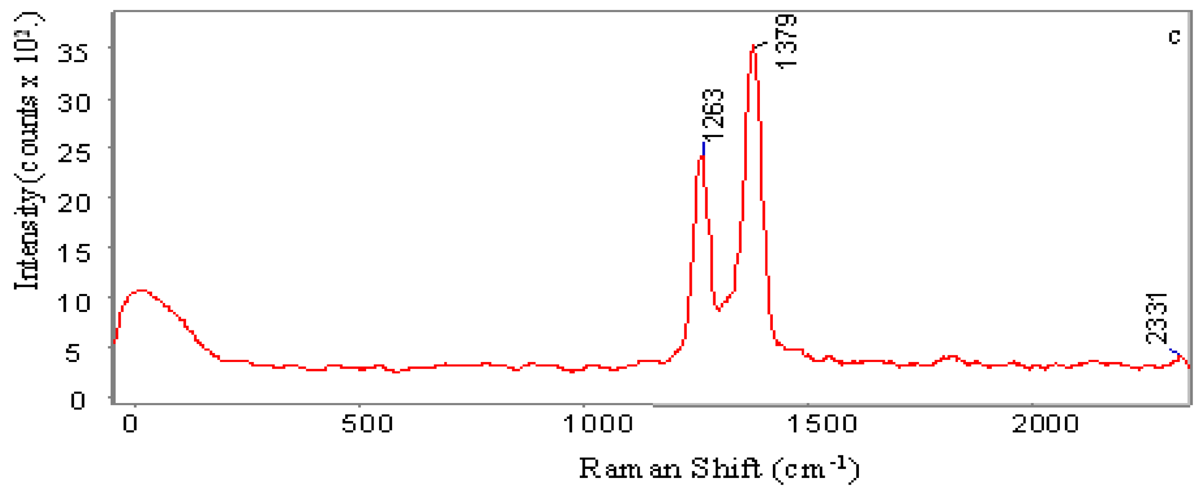
Remote Raman Fluorescence and Atmospheric Lidar Instrument

Raman-Fluorescence Mode

Laser beam in (a) pointed to the surface target sample in (b) at a 15 meter distance





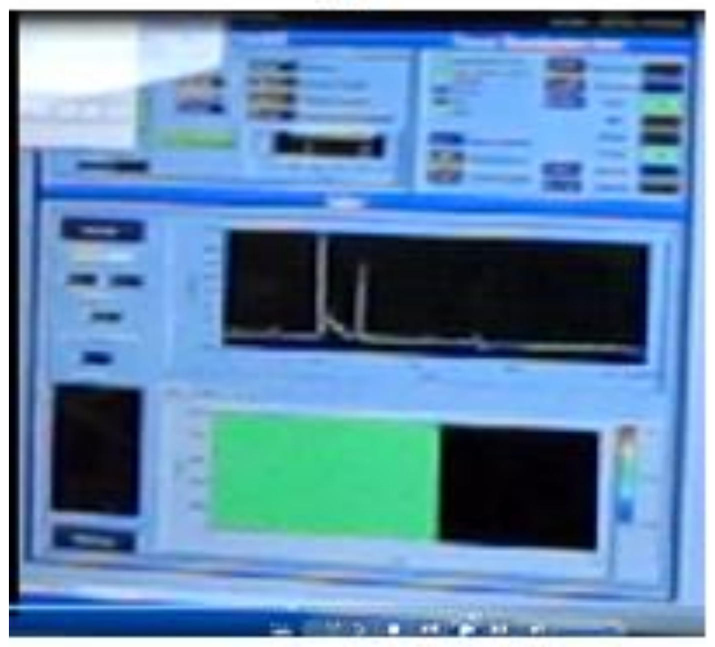


Raman spectra were acquired from water, ice, and dry-ice using the prototype instrument from a robotic platform at a distance of15 meter. Trace (a) shows the Raman spectra of liquid water and the strongest Raman bands are produced by the stretching vibrational modes. The Raman spectrum of ice in trace (b) shows a band around the same region as water, but it has a very strong and sharp band at 3119 cm^{-1} shifted down from 3281 cm^{-1} for liquid water because of ordering and stronger hydrogen bonding in water-ice. These changes in the O-H stretching Raman band of H_2O molecules in the ice are easily distinguishable from those of corresponding Raman features of liquid water. The Raman spectra of dry-ice (solid CO_2) in trace (c) are measured and the characteristic Fermi resonance doublet is due to the resonance between symmetric stretching mode and the harmonic of the IR active bending vibrational modes of CO_2 molecule [ref. 1]. In the dry ice, the sharp and narrow Fermi resonance Raman fingerprints of CO_2 are detected at 1262 and 1378 cm^{-1}.

Remote Raman Fluorescence and Atmospheric Lidar Instrument

Lidar Mode (>10 km range)

a

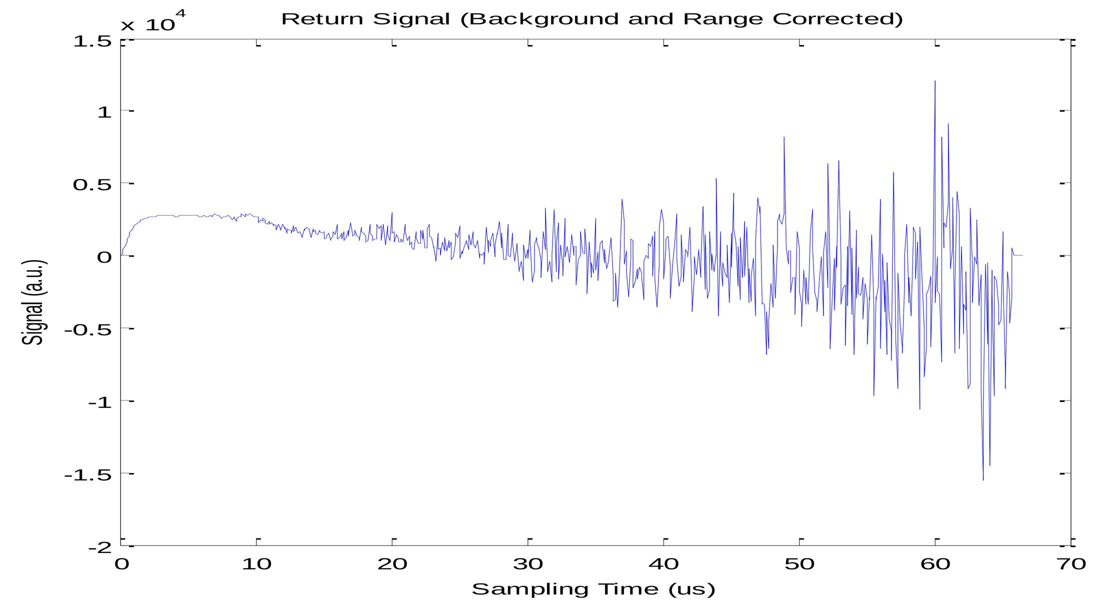


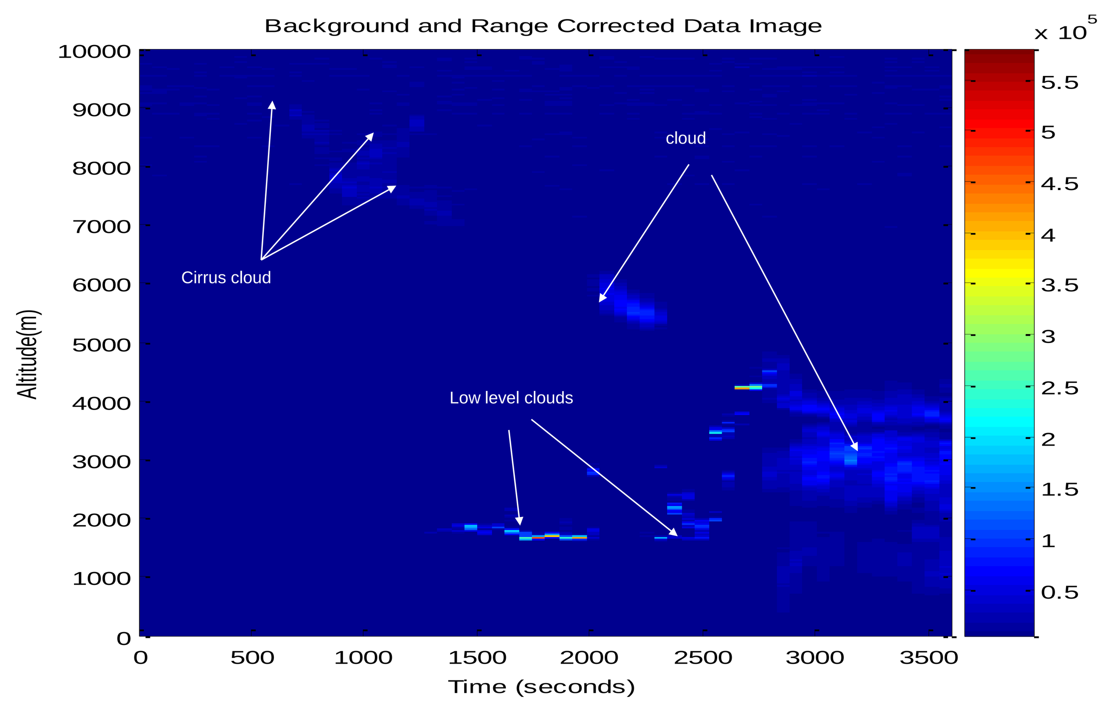
b

Laser beam pointed to the atmosphere in (a); real-time lidar data acquisition and display in (b)

Remote Lidar Response Using 100 mm Telescope

Atmospheric Return Signals from Cloud/Aerosols





Average atmospheric range corrected lidar signal profile (top trace) and image of range corrected signals (bottom trace) with 1 min or 1200 shot averaging. Lidar return signals were recorded on June 28, 2011, in the afternoon from 3:39 pm to 4:39 pm at LaRC.

Summary:

- We acquired Raman spectra from target samples (water, ice water, and dry ice) and characterized atmospheric aerosols and clouds under MIDP project.
- We have demonstrated a fully integrated remote Raman, Fluorescence, and Lidar Multi-Sensor prototype instrument onto a robotic platform at NASA Langley as an interim step towards development of a fully qualified and calibrated instrument for the Mars Sample Return (MSR)/Mars Astrobiology Explorer-Cacher (MAX-C), Asteroids/Comets, and other NASA SMD missions in the mid-to-long term.
- In addition, this integrated instrument is suitable for multi-platform applications on planetary surfaces and atmospheres such as those of Mars, Moon, Near Earth Objects (NEO), the moons of Mars and others as a precursor to future human exploration activities within NASA Human Exploration Operations Mission Directorate (HEOMD) missions.

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References:

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