PLANETARY SURFACES AND ATMOSPHERE CHARACTERIZATION USING COMBINED RAMAN, FLUORESCENCE, AND LIDAR INSTRUMENT FROM ROVERS AND LANDERS.

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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. 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.

There are mainly three parts of this multi-sensor instrument mounted onto the robotic platform. Part 1 consists of transmitter and receiver module. The key components of this transmitter and receiver module are a Nd: YAG laser from Fibertek to transmit three-wavelengths at 355-, 532-, and 1064-nm with a total laser energy of 45mJ, at a repetition rate of 20 Hz, a volume of 1596 cm^3, and a mass of 2.09 kg and also a 4-inch telescope. In part 1, laser beam transmits coaxially with respect to telescope to the surface or atmosphere. The backscatter signals are received by the telescope and pass to the sensor module (part 2) through fiber optics cable. The received signals comprise of three backscatter laser lines (e.g., 355 nm, 532 nm, and 1064 nm) including Raman- Fluorescence signals. A super notch filter (355 nm) is used to reflect the 355 nm laser line from the wave trains and a 355-nm laser signal is dumped. The other two laser lines (532 nm and 1064 nm) along with Raman-Fluorescence signals pass through this notch filter. A second notch filter (532 nm) is used to reflect 532 nm laser line to a Photomultiplier Tube (PMT) through focusing optics. The 532 nm laser line is used as a lidar channel. The rest of the signals including 1064 nm laser line transmit through this 532 nm notch filter. A third notch filter is used to reflect 1064 nm laser line from the wave trains and then a 1064-nm laser beam is dumped. The Raman and Fluorescence signals pass through focusing optics and a Langley-built compact grating spectrograph to an mini Intensified Charge-Coupled Device (ICCD) camera. This ICCD camera detects signal in the 530 nm to 700 nm spectral range, which provides the fingerprint of the molecules. Part 3 consists of data acquisition and power conditioning systems. Part 1 is mounted in the left arm of the rover system and then parts 2 and 3 are mounted in the back of the rover system as indicated in Fig. 1a.

This prototype instrument is suitable for multi-platform applications for remote sensing that is designed for surface backscatter signal (Fig. 1b) and upward/horizontal-looking return signal (Fig. 1c) detection from a rover system. This instrument is integrated and demonstrated on a mobile rover that is capable of performing both teleoperated and autonomous surface operations. 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.

Raman spectra were acquired from water, ice, and dry-ice using the prototype instrument from a robotic platform at a distance of 15 meter as shown in Fig. 2. Fig. 2a 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 Fig. 2b 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 Fig. 2c 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}.

Fig. 3 shows atmospheric features of the return signals for the PMT lidar channel at 532-nm. The data presented in the figures were analyzed with 1200 shot averaging (1 minute) to reduce noise. The profile spans between 0.0 to 10.0 km altitudes. The time spans between 0 to 3600 sec represents the lidar signals monitoring time with ~17-mJ/pulse (532 nm laser line) out of 45 mJ/pulse full laser energy (~14 mJ/pulse of 355 nm, ~17 mJ/pulse of 532 nm, and ~14 mJ/pulse of 1064 nm). Lidar return signals were recorded on June 28, 2011, in the afternoon from 3:39 pm to 4:39 pm at LaRC. Fig. 3a shows average atmospheric range corrected lidar signal profile and Fig. 3b shows image of range corrected signals. Aerosols and multi-layer clouds were detected with this 4-inch telescope. The multi-layer clouds were observed at around 9 km (cirrus cloud), 5.5 km, 3.5 km, 1.5 to 2.0 km altitudes.

In conclusion, we acquired Raman spectra from target samples (mixed minerals, 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:

[1] Sharma, S.K., *et. al.*, Proc. of SPIE 7691, pp. 76910F-1 – 76910F-11, 2010. [2] Abedin, M.N., *et. al.*, GSA annual meeting, 43 (5), p. 599, Minneapolis, MN, October 9 – 12, 2011.

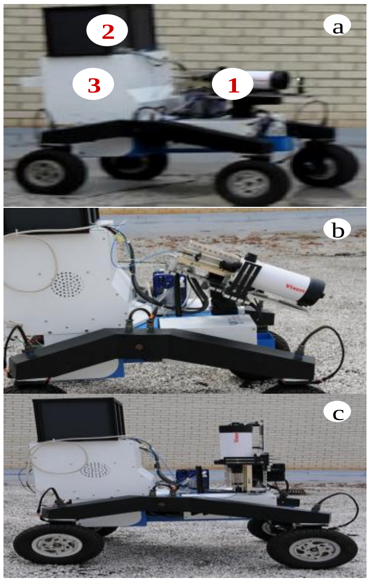

Fig. 1. (a) Part 1: Laser and 4-inch telescope, Part 2: Sensor Module, and Part 3: Data acquisition/power conditioning systems, (b) Operations of the combined in remote Raman-Fluorescence mode, and (c) in atmospheric lidar.

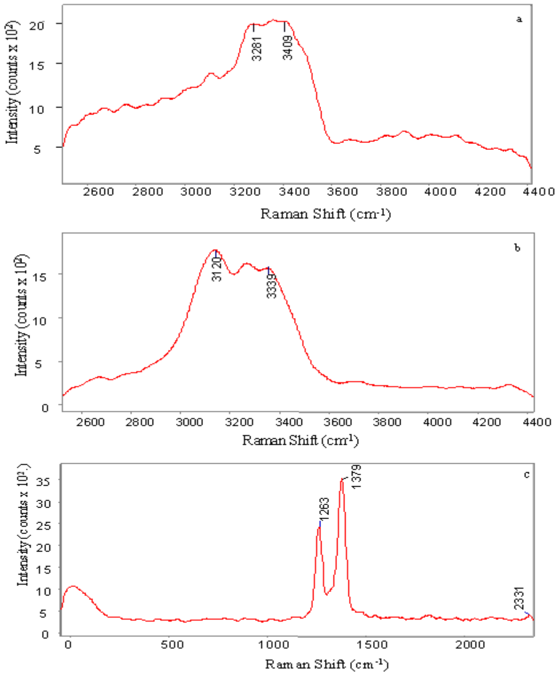

Fig. 2. Raman spectra of water (a), water-ice (b), and dry ice (solid CO_2) (c) from a distance of 15m.

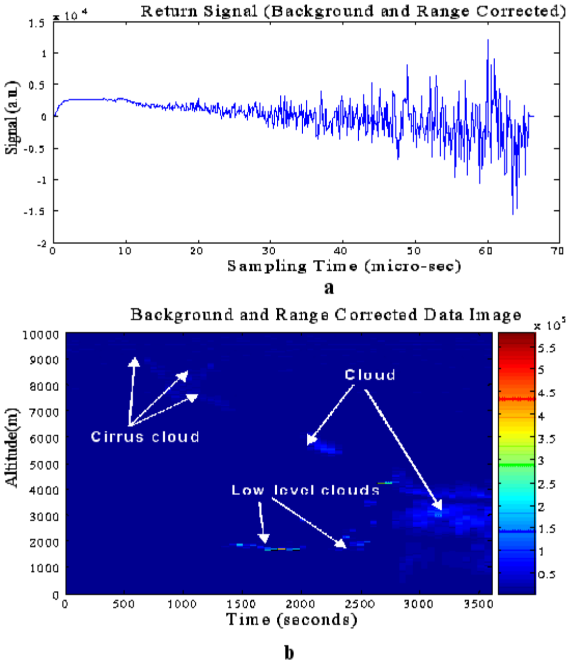

Fig. 3. Lidar return signals were recorded on June 28, 2011, in the afternoon from 3:39 pm to 4:39 pm at LaRC. (a) Average atmospheric range corrected lidar signal profile and (b) Image of range corrected signals with 1 min or 1200 shot averaging [ref. 2].