FROM CLOUDS TO LIFE DETECTION:
THE PAST, PRESENT, AND FUTURE OF LIDAR

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Introduction:

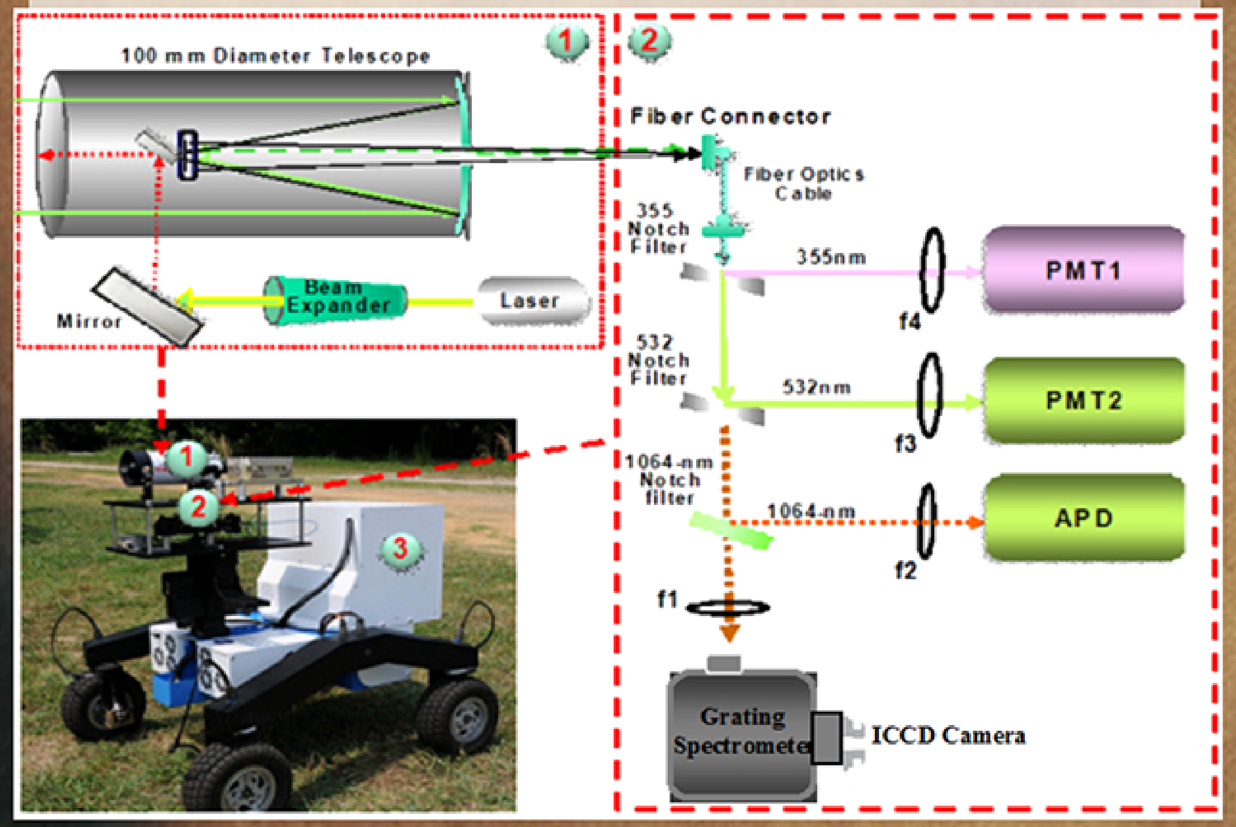
LIDAR or lidar, a portmanteau of light and radar, has expanded its utility significantly since its humble beginnings in the 1960's as a cloud measurement device. LIDAR has proven its worth beyond Earth especially as an orbital elevation-mapping tool, additionally *in-situ* LIDAR instruments have also proved useful. Recent advancements in LIDAR technologies are paving the way for exciting extraterrestrial applications with the capabilities to remotely detect surface mineralogy, surface organic materials and atmospheric constituents from rovers and landers [1].

The future is now and collaboration between researchers at NASA Langley and the University of Hawai'i has yielded an all-in-one compact remote Raman/Fluorescence spectrometer/LIDAR instrument.

Raman spectroscopy can uniquely classify surface mineralogy, organic and inorganic materials, and chemical compounds. Early Raman remote detection experiments used high-powered lasers and bulky spectrographs [2-5]. Although successful, these large-scale investigations are ill-suited for interplanetary missions, particularly landed platforms.

Advances in Raman spectroscopy have since improved this powerful spectral analyzer to be desirable for extraterrestrial endeavors. Fluorescence can be removed to isolate Raman backscatter, or studied separately using recently discovered time-resolved techniques. Time-resolved fluorescence is optimum for detecting polyaromatic hydrocarbons (PAHs) and biomolecules, which could be applied to the *in-situ* measurements on planetary surfaces such as Mars, Venus, Europa, etc. [5].

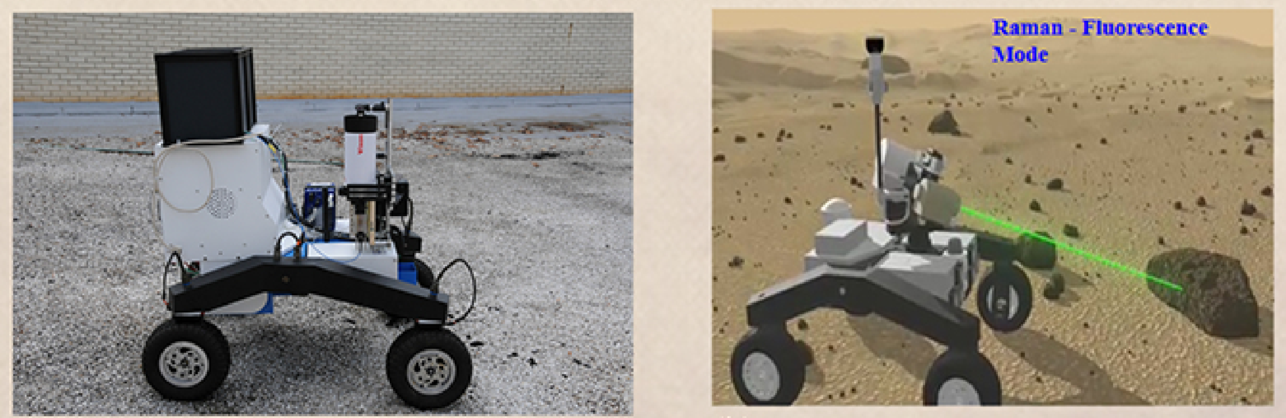
Remote Raman-Fluorescence & Lidar Instrument



Main components of the Raman and fluorescence grating spectrometer with lidar receiver system: pulsed Nd:YAG Laser, beam expander, steering mirror, mirror-2 attached with 100 mm telescope, PMT2 (lidar channel), optics. Sections 1 and 2 are mounted at the left arm of the rover, CPU control unit, power supply, ADC, pulse generator, and interface (not seen here) mounted at the back of the rover system.

Venus' lower-atmosphere and surface studies present particular challenges to Raman techniques, since the intense thermal noise extends well into the infrared. Ultraviolet lasers are particularly interesting in this regard, as they both increase the Raman signal and avoid the thermal noise. Raman techniques have an advantage over direct sensing techniques (e.g. GCMS) in that they can operate through a window and do not need access to the environment. Ongoing studies, based out of NASA Langley and the University of Hawai'i, are further optimizing remote LIDAR capabilities as powerful spectral detectors by using higher laser power (1-Joule/pulse), and a large telescope (1 to 2 m). This design could be used both on a lander/rover on a surface or on a balloon or orbiter, making Raman/fluorescence measurements from 5 cm -10,000m away [6,7]. [*See figure* 1]. In this poster we will present ongoing and future applications of LIDAR, and its implications for astrobiology in greater depth.

Remote Raman Fluorescence and Atmospheric Lidar Instrument

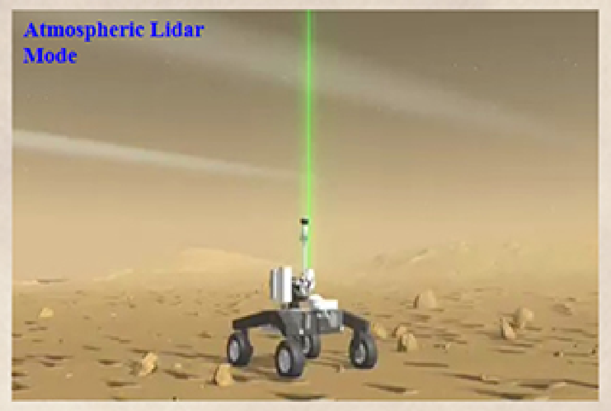


(a) (b)

Laser beam in (a) pointed to the surface target sample (b) future applications of remote Raman on a planetary surface rover.

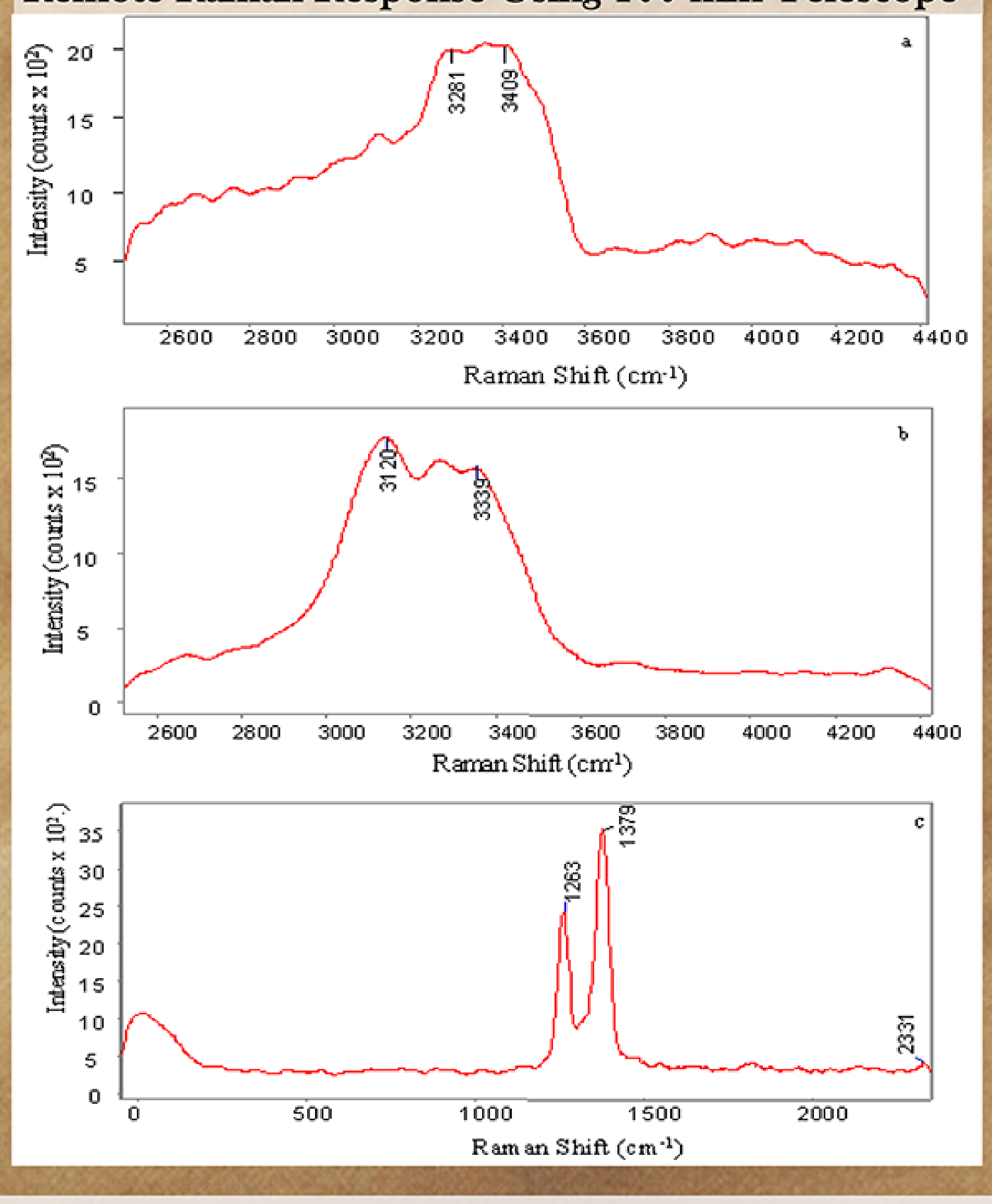
At NASA Langley, future studies will include remote Raman testing on various planetary analog samples including Venusian surface simulations, Europa like conditions, and a wide range of organic and biogenic minerals.

Such tests are vital to the success of remote Raman detection, as the capabilities of such an all-in-one instrument will greatly improve humanity's ability to detect life elsewhere. The following images and figures convey the early success of mineral and atmospheric detections



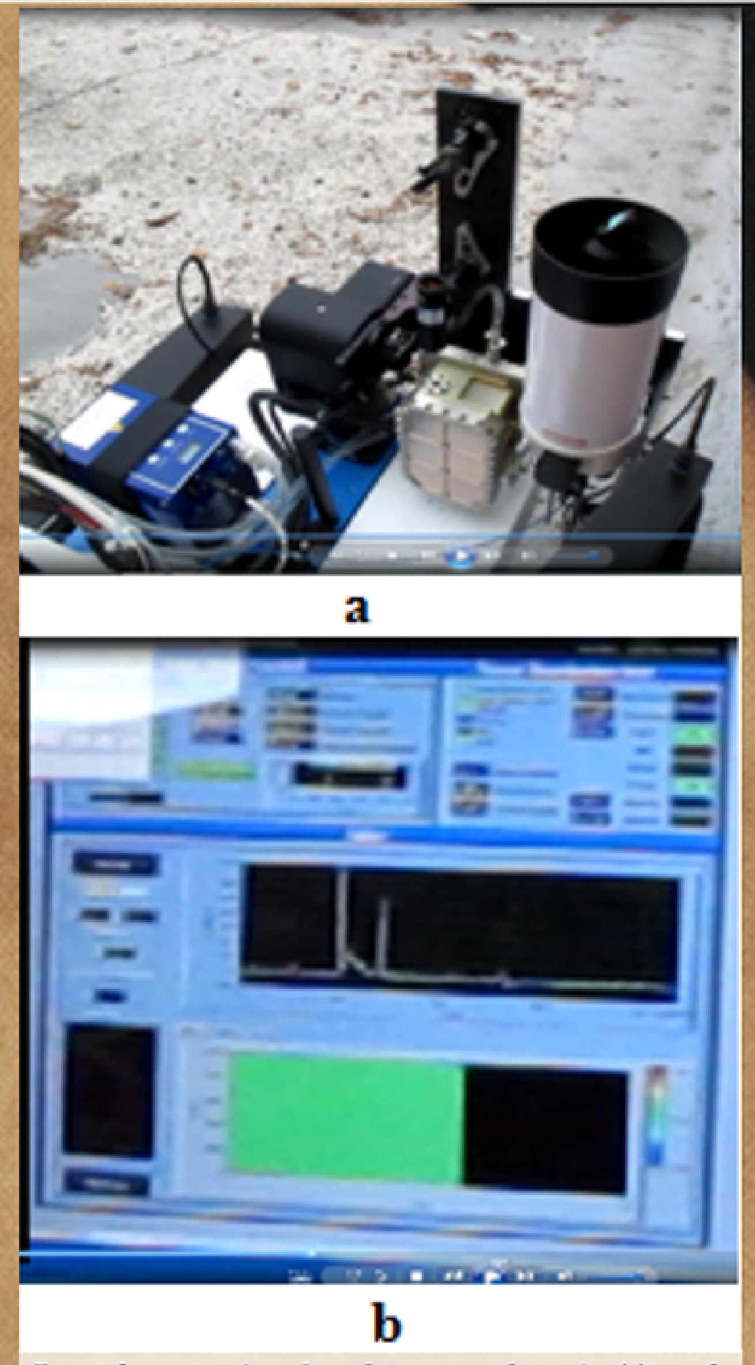
Example of a Martian rover implementing atmospheric Lidar measurements

Remote Raman Response Using 100 mm Telescope



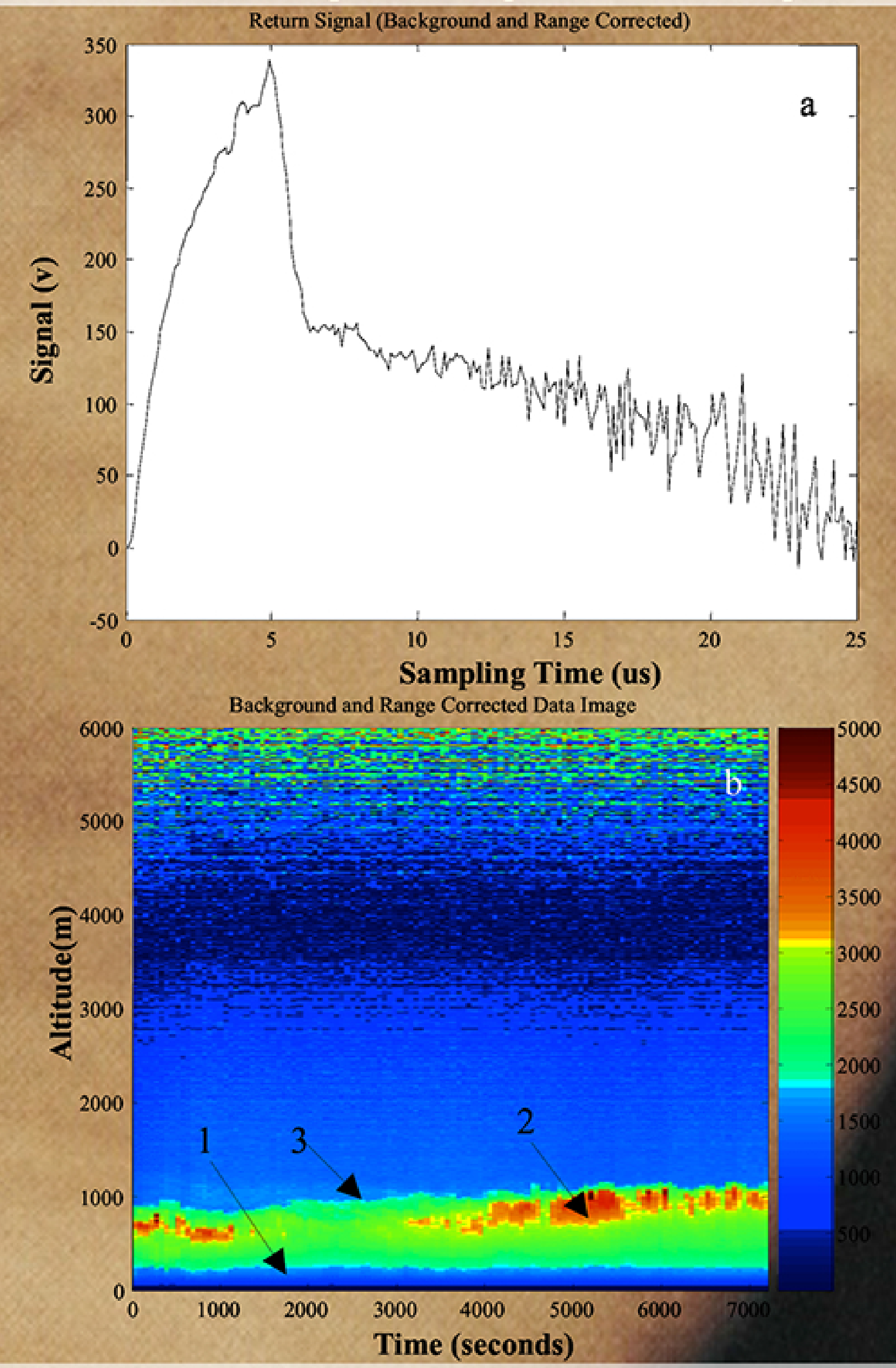
Raman spectra were acquired from water, ice, and dry-ice using the prototype instrument from a robotic platform at a distance of15 meter. Trace (a) shows the Raman spectra of liquid water and the strongest Raman bands are produced by the stretching vibrational modes. The Raman spectrum of ice in trace (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. 5]. 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 operating in Lidar Mode (>10 km range)



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

Atmospheric Return Signals from Cloud/Aerosols Remote Lidar Response Using 100 mm Telescope



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 April 20, 2012, in the afternoon from 2:09 pm to 4:10 pm at LaRC.

References:

[1] M. N. Abedin, et al. [Abstract]. 42nd Lunar and Planetary Science Conference. Pg. 2298 (2009). [2] T. Hirschfeld, Appl. Opt. 13, 1435-1437 (1974). [3] S. M. Angel, T. J. Kulp, and T. M. Vess, Appl. Spectrosc. 46, 1085-1091 (1992). [4] P. G. Lucey, T. F. Cooney, and S. K. Sharma, Lunar Planet. Sci. XXIX, Abstract #1354. [5] M. N. Abedin, et al., Appl. Opt. 52, 3116-3126 (2013). [6] S.M. Angel, et al., Appl. Spectro., 66, 137-150 (2012). [7] S.K. Sharma, et al., 45th Lunar and Planetary Science Conference, Abstract #1678, (2014).

All images and figures courtesy of Dr. Nurul Abedin, NASA Langley