

A REMOTE RAMAN ANALYSIS SYSTEM FOR PLANETARY LANDERS. Paul G. Lucey, Thomas F. Cooney, Shiv K. Sharma, Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, 2525 Correa Rd. Honolulu, HI 96822, USA (lucey@kahana.pgdl.hawaii.edu).

Landers and rovers are an increasingly important element of the NASA's solar system exploration program. Lander and rover sample analysis instrumentation includes methods requiring either close physical contact with a sample such as XRF spectroscopy, or even sample acquisition, such as thermal analysis or mass spectrometry. Sample selection is accomplished using imaging supported by multispectral or remote spectroscopic analysis. The recent experience with Sojourner/Pathfinder emphasized the importance of sample selection as contact analyses are intensive in time or other resources. Capable multispectral imaging and imaging spectroscopy are invaluable to sample selection, but there are inherent limitations to these techniques, and limits to their performance at their present state of development.

Raman spectroscopy is a powerful technique for mineralogical analysis commonly used in terrestrial laboratories and being actively proposed for *in situ* analysis on planetary landers [1]. Raman analysis has a number of advantages over passive spectroscopy, chief among them being the sharpness of spectral features due to minerals and ices which allow much less ambiguous detection. Theory and experiment have shown that Raman analysis can be conducted remotely at ranges of tens of meters. We have conducted a proof of concept experiment to show that high quality diagnostic Raman spectra of materials of planetary interest including ice, carbonate, sulfate and silicate can be obtained at a range of over 10-m with laser power and spectral analysis equipment appropriate for a landed package. This is an entirely new capability which does not currently exist in the toolkit available to the planetary science community.

The potential for performing Raman analysis remotely was explored theoretically by Hirschfeld (1974) [2], and experimentally by Angel *et al.* (1992) [3]. The latter study measured the Raman spectra remotely of highly covalent molecular compounds which have much stronger Raman emission than those of common minerals. We undertook a proof-of concept experiment to show that quality Raman spectra could be obtained remotely of materials relevant to solar system exploration.

We successfully measured Raman spectra of a number of mineralogical samples from a distance of 11.4 meters (37 feet). A diagram of the experimental setup is shown in Figure 1. The system used a receiver consisting of a four-inch diameter reflecting telescope with a fiber-optic pickup feeding a compact Raman spectrograph equipped with a Reticon line array detector. For these initial tests, a research grade argon-ion laser and an imaging grating spectrograph were employed. Sampling size (laser spot size at the sample) was approximately 2 cm². The telescope optics and distance the sample were such that the image of this spot almost perfectly matched the 350 μm fiber bundle. The laser power was kept relatively low (100-500mW) to simulate the output of a solid-

state laser. Total exposure times were from one to several minutes.

Some initial results from the laboratory experiments are shown in Figs. 2 and 3. We measured the spectra of marble (metamorphic carbonate), a forsteritic olivine, water ice and gypsum all from a range of 11.4m. Features diagnostic of sulfates, carbonates and silicates, as well as features enabling distinguishing different forms of H₂O are readily apparent.

This proof-of-concept experiment has shown that Raman spectra can be obtained with reasonable laser powers (the Clementine laser altimeter emitted 170mW), a modest telescope size (4 inches), a receiver which can be readily miniaturized, with integration times which are modest, and for distances which are relevant to planetary landers. The detector array used was not nearly as sensitive as a CCD array and considerably better results could be achieved with such a detector.

For this concept to be viable for a lander or rover, the amount of data collected remotely must be of such quality and quantity that it is more cost effective from a systems standpoint than contact measurements. Given the severe constraints on mass and power in a lander implementation, we currently are studying the tradeoff between range to target, target object (e.g. Mars vs. Europa), detector dark current and sensitivity, laser wavelength and detection wavelength, laser power, collection aperture area, integration time and signal to noise ratio.

This concept provides an entirely new measurement capability which complements passive remote sensing, and may eliminate the need for some kinds of mobility or additional mobility operations *in situ* measurements requiring sophisticated sample acquisition systems or sample head deployment.

References: 1) Wang, A, B.L. Jolliff, and L.A. Haskins, *J. Geophys. Res.* 100 (E10) pp21189-21199, 1995. 2) Hirschfeld, T. (1974), *Appl. Optics* 13, 1435-1437.3) Angel, S.M. Kulp, T.J. and Vess, T.M. (1992) *Appl. Spectrosc.* 46, 1085-1091.

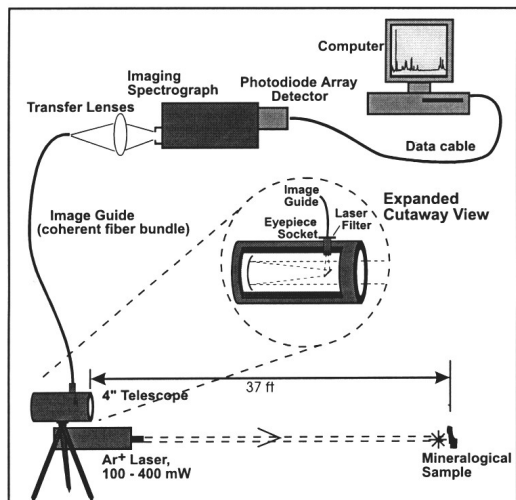


Figure 1. Sketch of experimental setup for proof-of-concept remote Raman experiment.

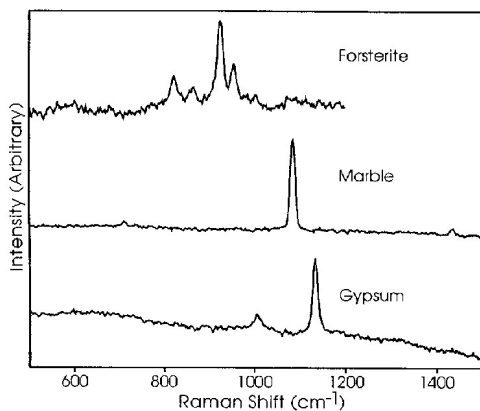


Figure 2. Raman spectra obtained from a distance of 11.4 - m using the setup shown in Figure 1. Features due to silicate, carbonate, and sulfate are easily seen

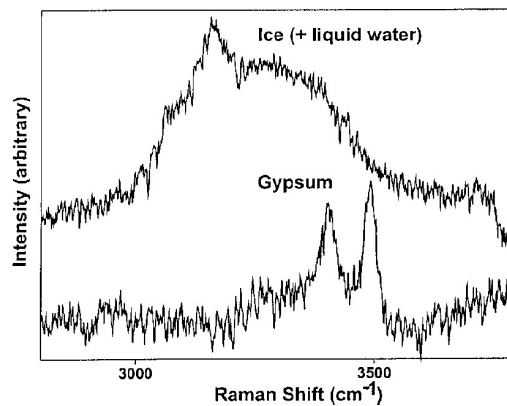


Figure 3. Remotely obtained Raman spectra in the OH/H₂O region. These were collected using the setup shown in Figure 1. The distinct forms of OH and H₂O are apparent. The broad shape in the ice spectrum is due to a coating of liquid water. The sharper peak near 3150 wavenumbers is diagnostic of crystalline ice. Structural water is seen near 3500 wavenumbers.