Lunar Raman Deep Ultraviolet Visible Spectrograph (LR-DUV-VIS) Concept. K. D. Retherford[1,2], T. Z. Moore[3], M. A. Miller[1], P. M. Molyneux[1], A. Whizin[1], R. C. Blase[1], U. Raut[1,2], T. J. Veach[1], A. Reisig[1], J. Bartlett[1], R. A. Klar[1], M. A. Freeman[1], and S. P. Schwenzer[4]; [1]Southwest Research Institute, San Antonio, TX (kretherford@swri.edu), [2]University of Texas at San Antonio, San Antonio, TX, [3]Fibertek, Herndon, VA, [4]The Open University, Milton Keynes, UK.

Introduction: Lunar volatile delivery and subsequent modern-day transport is of great interest for in situ resource utilization. Measurements of the relative compositions of volatile ices in Permanently Shadowed Regions (PSRs) are needed to constrain the history of these volatiles. As previously demonstrated, the relative ratios of C-H-O-N-S volatile species are diagnostic of the key source and loss processes for lunar volatiles [1]. The mineral inventory of individual rocks and full regions can distinguish the influence of numerous geophysical processes (e.g., impacts, volcanism, and space-weathering/maturity). Assessments of lunar mineral trace species, hydration states, and space weathering (npFe0/SMFe) related alterations of olivine and plagioclase feldspar provide relative chronological constraints for investigating surface evolution. Raman spectroscopy is well suited for these volatile and mineralogical studies, making it destined to become a core lunar payload instrument.

Instrument Concept: The Lunar Raman Deep-Ultraviolet Visible Spectrograph (LR-DUV-VIS; e.g., "du-viz") concept advances a dual-laser Deep-UV+Visible Raman system capable of detecting complex molecules and performing compositional assays with a fiber optic coupled focusing lens sensor. Lunar Raman DUV-VIS is suitable for lunar landers, rovers, Artemis EVA stations, and the lunar terrain vehicle, as it constrains volatiles in PSRs, mineral hydrated states, and key mineral abundances. A breadboard Raman spectrograph has been developed through SwRI IR&D (Fig. 1). Our multi-fiber coupled spectrograph approach combines a standard focusing lens sensor for individual spot sampling, with two channels, Deep-UV (DUV) and Visible (VIS), for disentangling Raman and fluorescence signals from each species.

Design: Our two-channels-in-one Raman approach uses the same multi-fiber coupled spectrograph with one sensor frontend and two lasers, offering the advantages of both DUV and VIS Raman techniques to mission concepts according to science objectives. Two spectrograph channels feed one CMOS detector for compactness. Advantages for DUV Raman excitation include resonance of electronic transitions in molecules leading to greatly enhanced intensity of scattering signal and avoidance of the autofluorescence spectral region, ideal for detecting trace amounts of carbonaceous volatiles and determining deuterium to hydrogen ratios in water ice. The VIS channel is well suited to surveying relative abundances of oxygen bearing minerals, complementing the DUV channel. The DUV laser emits at a wavelength of 266 nm and the VIS at 633 nm. A key attribute of the VIS channel is its coverage of phonon modes at very low wavenumbers into the THz frequency range, probing molecular orientation, crystallographic variances, and further constraining mineral types.

The compact design and low resources for LR-DUV-VIS enable it to be a core part of a PRISM suite. LR-DUV-VIS's focusing lens sensor samples spots of diameter 50-100 µm in the workspace of a lander, rov-

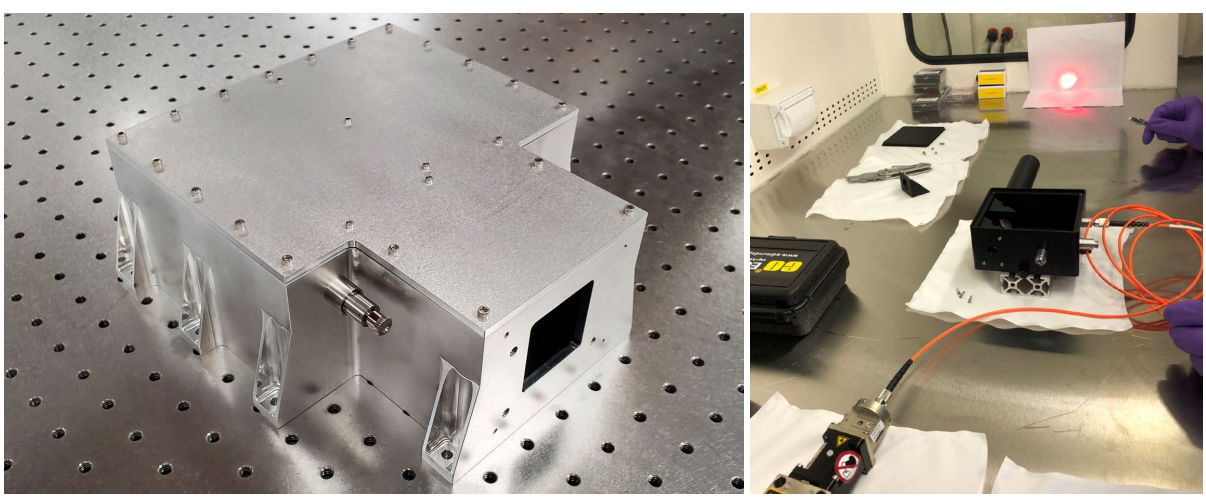

Figure 1. LR-DUV-VIS SwRI IR&D Spectrograph (left) and Focusing Lens (right) prototypes (TRL 4 demonstration).

er, or Artemis workstation. A low cost commercial visible camera is added to the sensor head for context imaging of the focusing lens target.

Internal Research Progress and Future Plans: A TRL 4 system level breadboard built using SwRI IR&D funds has demonstrated basic functionality for new components. Other instrument components are already at TRL ≥ 6. Related prototypes and commercial Raman systems at SwRI have produced example spectra of Apollo samples and simulants (Fig. 2) [2,3]. Future work includes customization of the instrument concept for continuous wave DUV 266 nm and VIS 633 nm Raman lasers, developed for flight by Fibertek in partnership with TOPTICA Photonics. Several research programs will be pursued in the next few years to leverage the capabilities of this Raman system to measure a range of different materials relevant to lunar science.

Brief Summary (Haiku form):
Lunar Raman light /
Deep UV and Visible /
Spectrograph observes

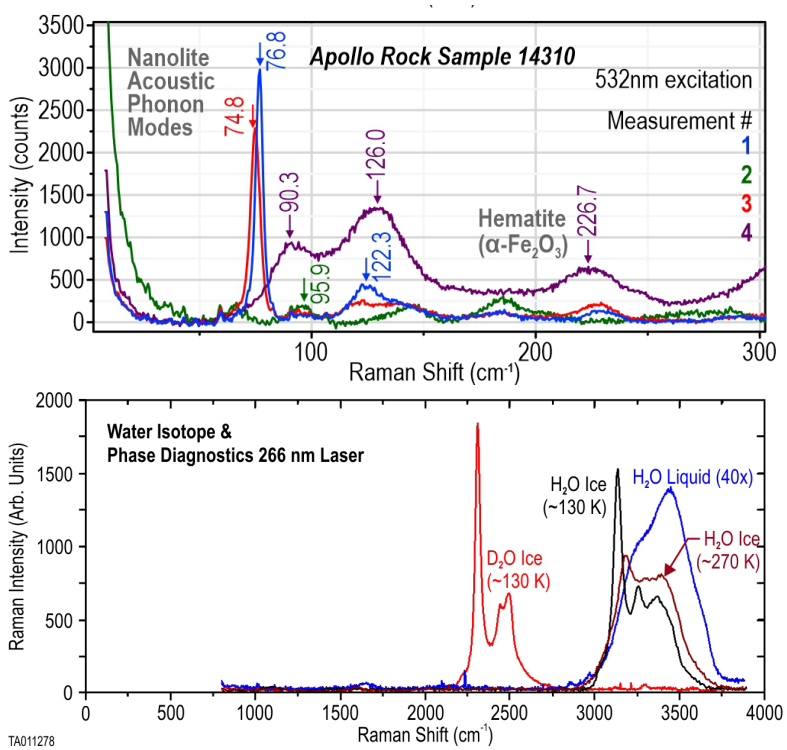

Figure 2. (top) Raman spectra of Apollo sample 14310 measured at SwRI, demonstrating phonon mode and hematite peaks captured with LR-DUV-VIS's expected $\Delta\nu \sim 1$ cm^{-1} resolution and high contrast. (bottom) SwRI's related integrating cavity sensor prototype (TRL 6) produced these spectra of water ice, deuterated water ice, and temperature/phase Raman signatures obtained with a Deep-UV 266 nm laser source.

References:

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