THERMAL INFRARED EMISSION AND GONIOMETRIC LABORATORY MEASUREMENTS. I. R. Thomas[1], N. E. Bowles[1], T. Warren[1], B. T. Greenhagen[2], K. L. Donaldson-Hanna[3] and D. A. Paige[4].
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Introduction: The Diviner Lunar Radiometer is a high-resolution, nine-channel mapping radiometer currently orbiting the Moon onboard NASA's Lunar Reconnaissance Orbiter (Table 1). The '8 µm' channels are used to map the spectral location of the Christiansen Feature (CF), a mid-infrared emissivity maximum, the wavelength of which is highly dependent on surface composition [1].

Channel	Wavelength	Purpose
A1	0.35 – 2.8µm	High Sensitivity Solar
A2	0.35 – 2.8µm	Mid Sensitivity Solar
A3	7.55 – 8.05µm	Christiansen Feature
A4	8.1 – 8.4µm	Christiansen Feature
A5	8.4 – 8.7µm	Christiansen Feature
A6	13 – 23µm	Thermal
B1	25 – 41µm	Thermal
B2	50 – 100µm	Thermal
B3	100 – 400 µm	Thermal

Table 1: Diviner channel descriptions [2]

The shape and wavelength of the CF is affected by the lunar environment [e.g. 3,4,5 etc.], making it difficult to compare observations to most existing mid-infrared spectral libraries; hence new measurements made in a simulated lunar thermal environment are required. Also, scattering properties at mid-infrared wavelengths are poorly constrained at present; therefore, to further understand Diviner and other airless body infrared observations, several experiments have been built (and continue to be built) at the Planetary Spectroscopy Facility. These include the following:

(a) chamber for measuring the mid- and far- infrared emissivity of minerals and lunar samples in a simulated lunar environment (SLE);

(b) multiple-angle infrared reflectance apparatus;

(c) mid- and far- infrared goniometer, which is currently under construction.

New measurements taken with these will be presented.

(a) Simulated Lunar Environment Chamber: The SLE chamber induces a temperature gradient within the sample of ~equal magnitude to that induced by the lunar thermal environment. This is done in one of two ways, either by heating from below (Figure 1) [6]

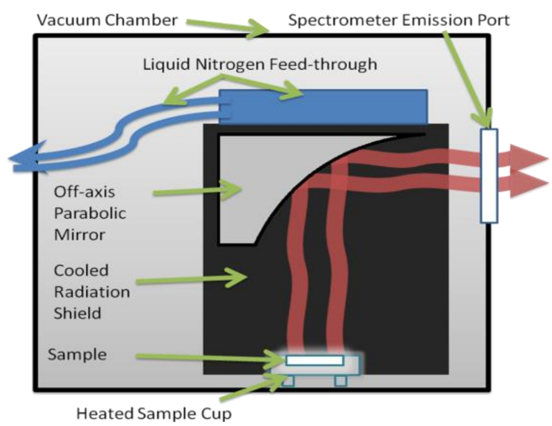

Figure 1: The heating-from-below setup

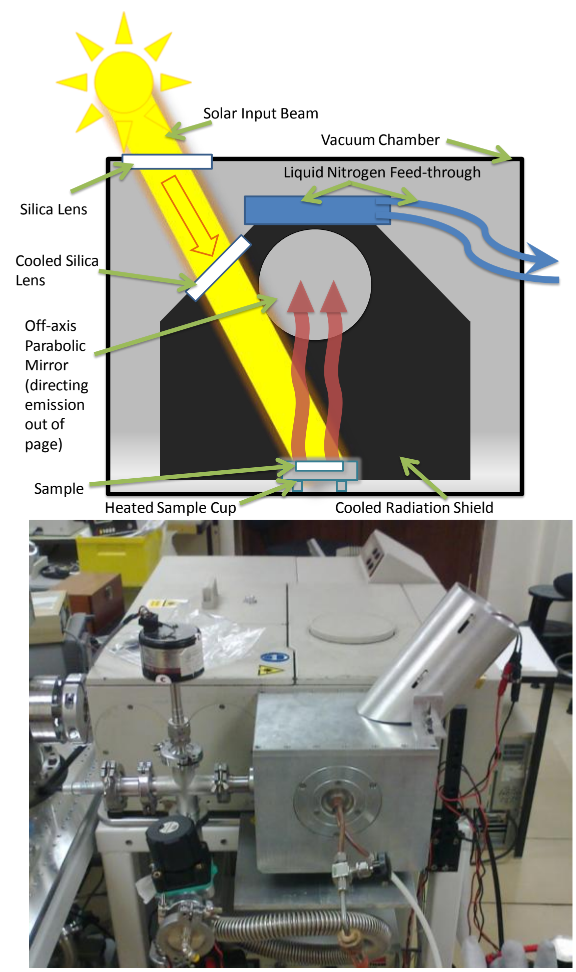

Figure 2: Heating-from-above schematic and photo

or above (Figure 2). This chamber has been used to measure a diverse range of materials including pure mineral particulates [7] and lunar soils [8], and is currently being upgraded with a sample-changer to increase the sample measurement rate.

(b) Multiple-angle Infrared Reflectance: This setup uses a Specac Monolayer Grazing Angle Accessory to measure the infrared reflectance of a sample at variable incidence and emission angles. It consists of two independently controllable arms: one directs the beam from an FTIR spectrometer onto a sample, while the other directs the reflected radiation to a detector (Figure 3) [9].

Although the lunar thermal environment is not simulated during this measurement, scattering and surface roughness properties can be investigated using this setup, and it provides good middle-ground between the SLE chamber (which measures continuous spectra but at a single, fixed emission angle) and the goniometer (which measures at variable geometry but only with limited spectral passbands).

Figure 3: Multiple-angle reflectance accessory

(c) Infrared Goniometry: The goniometer has been designed and is currently under construction. It will consist of two arms, similar to the multiple-angle reflectance accessory described above, except that the arms will also be able to rotate azimuthally and will simulate the lunar environment (Figure 4). A solar lamp is attached to one arm, while a detector with Diviner flight-spare filters [Table 1] is attached to the other, surrounded by a radiation shield cooled to <150K and enclosed in a $<10^{-3}$ mbar vacuum chamber to simulate the lunar environment. The system is designed to have comparable angular accuracy and angular range of similar reflectance goniometers (e.g. [10]). In future the system will be coupled to a FTIR spectrometer to allow full spectro-goniometric measurements to be made.

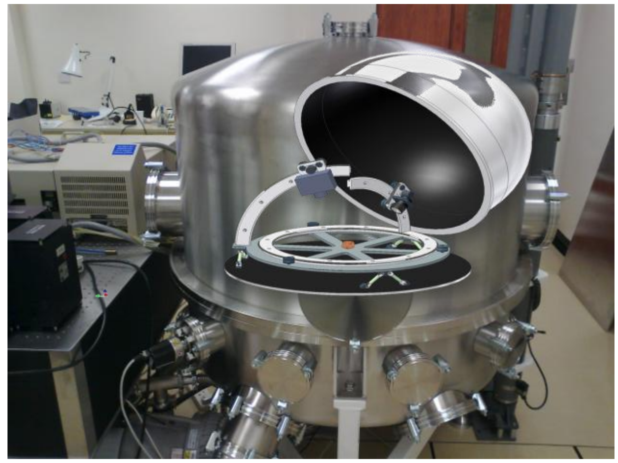

Figure 4: Goniometer CAD model superimposed on the vacuum chamber.

Conclusion: The Planetary Spectroscopy Facility continues to design and build leading laboratory experiments necessary for the correct interpretation of mid-infrared observations of the Moon by Diviner [e.g. 11]. These experiments can be extended to assist in the interpretation of other airless bodies, such as the OTES spectrometer due to fly on OSIRIS-REx. The development of the goniometer (and later the spectro-goniometer) are continuing this advancement.

References: [1] Greenhagen B. T. et al. (2010) Science, 329, 1507; [2] Paige D. A. et al. (2009) The Diviner Lunar Radiometer Experiment, Space Sci. Rev. 150, 125-160; [3] Nash D. B. et al. (1993) J. Geophys. Res., 98, 23535-23552; [4] Henderson & Jakosky (1997) J. Geophys. Res., 102, 6567-6580; [5] Logan et al. (1973) J. Geophys. Res., 78, 4983-5003; [6] Henderson et al. (1996) J. Geophys. Res., 101, 14969-14975; [7] Donaldson-Hanna, K. L. et al. (2012), J. Geophys. Res., doi:10.1029/2011JE003862, in press. [8] Greenhagen B. T. et al. (2012) LPSC 43; [9] Specac Ltd. (2011) ”Monolayer Grazing Angle Accessory”, Retrieved from: http://www.specac.com/products/ft-ir-specular-reflectance-accessory; [10] Shepard, M. K. (2001) LPSC 32, 1015; [11] Glotch T. D. et al. (2010) Science, 329, 1510.