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Thermal-Infrared Laboratory Measurements in Support of the Diviner Lunar Radiometer

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Abstract

Diviner's unique high-resolution thermal-infrared (TIR) observations have opened up a new spectral region with which the Moon can be explored. New spectral regions, however, also require new laboratory experiments to allow interpretation of returning data, which in the case of the TIR region is complicated by the effects of the lunar environment. In the Atmospheric, Oceanic and Planetary Physics Dept. of Oxford University a new laboratory has been constructed that includes an emission chamber to simulate conditions on the lunar surface and will soon contain an infrared goniometer. This new laboratory will allow us to make new infrared measurements under lunar conditions so that a lunar emissivity spectral library can be created.

1. Introduction

1.1 Diviner

Diviner (Instrument PI: David Paige, UCLA) is a nine-channel mapping radiometer currently orbiting the Moon onboard the Lunar Reconnaissance Orbiter with a surface resolution of <400m. The instrument consists of two solar channels (0.35 – 2.8 µm), three '8 µm' channels (7.55 – 8.05, 8.1 – 8.4 and 8.4 – 8.7 µm) and four thermal channels (13 – 23, 25 – 41, 50 – 100, and 100 – 400 µm) [8]. The '8 µm' channels are specifically designed to map the spectral position of the Christiansen Feature (CF) to constrain lunar surface composition [1], while the longer-wavelength channels measure surface brightness temperature from 25 K to over 400 K.

1.1 The Lunar Environment

The CF is a mid-infrared (MIR) emissivity maximum, which due to enhancement by the lunar environment is a prominent spectral feature observed in the MIR spectra of lunar minerals, and is also a good compositional indicator [1,4,5,6,7]. This enhancement is caused by a large thermal gradient developed in the top few layers of the sample due to the very low thermal conductivity of the lunar regolith and very low pressure atmosphere. While the daytime solar radiation heats the top few centimetres of regolith, only the top microns of the surface radiate to space in the MIR, and are therefore cooled. The CF peak, located where the spectrum is most transparent, is therefore enhanced as radiation is emitted from hotter, deeper layers in the surface [2,3,4,5,6,].

2. Emissivity Measurements: Heating from Below

An emission chamber was built to simulate the temperatures and pressures experienced on the lunar surface (Figure 1), which is attached to a Brüker IFS-66v Fourier Transform Spectrometer. The thermal gradient described above can be replicated by heating a sample from below to 500K, whilst the sample is surrounded by a high-emissivity radiation shield cooled to 100-150K to simulate cold space; all under a pressure of less than 10^{-6} bar, as shown by [2].

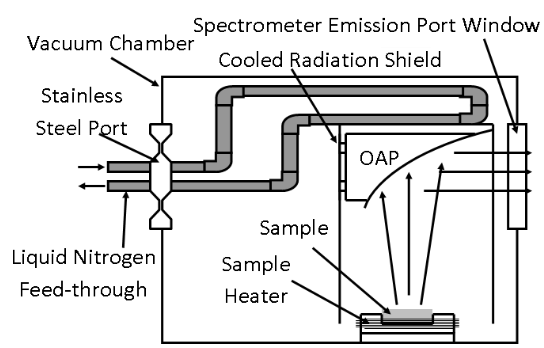

Figure 1: A simplified diagram of the inside of the emission chamber with the main parts labeled.

Heaters are attached to the off-axis paraboloid (OAP) mirror to prevent vapour given off by the sample from contaminating the mirror, which for measurements is cooled with the radiation shield. Calibration of the spectrometer is achieved by making regular high resolution measurements of a blackbody at known temperatures, as is done in other emission setups. Some of the samples measured so far and their corresponding lunar-environment CF peak wavelengths are listed in Table 1. This heating-from-below method has been shown to work well for minerals with narrow grain size distributions.

Sample	Grain size (μm)	CF (μm)
Anorthite	0 - 25	7.82
Labradorite	0 - 25	7.60
Andesine	0 - 25	7.61
Oligoclase	0 - 25	7.40
Albite	0 - 25	7.53
Forsterite	0 - 30	8.68
Fayalite	0 - 30	8.99
Augite	0 - 30	8.13
Enstatite	0 - 30	8.12

Table 1: A selection of the samples measured so far and their CF peak wavelengths.

2. Emissivity Measurements: Heating from Above

Some samples though, especially those containing mixtures, rocks or wide grain size distributions, did not behave as expected when heated-from-below, and so the chamber was modified (Figure 2). The addition of a solar-like halogen lamp allows the sample to be heated from above, through a small aperture in the cold-shield, as would occur on the lunar surface, similar to the experiments of [4,5,6]. This setup is being used to measure several Apollo samples, rocks and mixtures.

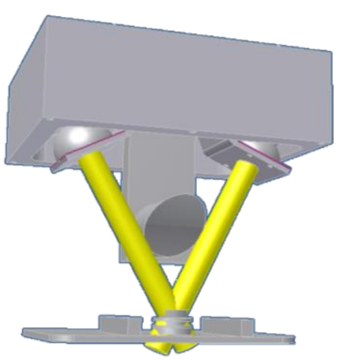

Figure 2: CAD model of the heating-from-above setup, showing the illumination of the sample.

3. Thermal-Infrared Goniometry

To better understand the Diviner data and for inclusion into computer thermal models, the scattering properties of infrared radiation by the lunar surface need to be investigated. Reflectance goniometry has been performed previously, but making such measurements under lunar conditions in the TIR requires a new setup, which is currently being developed (Figure 3).

Figure 3: CAD model of the goniometer, showing the surrounding cold-shield, solar source and detector mounted on computer-controlled moveable arms. All of this would be placed in a low-pressure vacuum chamber to simulate the lunar environment.

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