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The Oxford Space Environment Goniometer.

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Abstract

Measurements of the light scattering properties of airless bodies in the Solar system, across wavelengths from the visible to the thermal infrared are essential to understanding their surface properties. This paper describes work currently under way to develop a novel 'Space Environment Goniometer' (SEG). The SEG allows phase function measurements of regolith simulant samples to be made under vacuum (<10^{-4} mbar) whilst enclosed by a cooled (<150 K) radiation shield. The cooled radiation shield reduces the thermal background allowing phase measurements from the visible to the thermal infrared to be made.

1. Introduction

This work was originally motivated by the need for new emission phase function measurements to support analysis of data currently being returned by the Diviner Lunar Radiometer ('Diviner') instrument. Diviner is a nine-channel mapping radiometer on board NASA's Lunar Reconnaissance Orbiter. It has channels ranging from the visible to the far infrared (>400μm) [4], with three channels centred on the mid-infrared (8μm).

Typically, 3D thermal physical models of the lunar surface, which attempt to reproduce the brightness temperatures measured by Diviner [e.g. 3,7], assume infrared radiation is scattered isotropically from the lunar surface. Although generally the models are in very good agreement with the measured brightness temperatures, there are some discrepancies [3] and one possible reason for these discrepancies is that the scattering properties of the regolith in the mid-infrared are incorrectly estimated in the models. Although significant progress is being made in determining the scattering properties of the lunar soil in the visible and near-infrared [e.g. 1], there is still limited or no data available on the scattering properties in the thermal (TIR) or far infrared (FIR).

We are therefore developing an automated, vacuum compatible goniometer system capable of measuring the bidirectional distribution reflectance function (BRDF) in the TIR and FIR of samples under simulated lunar thermal conditions in the laboratory at the same wavelengths as Diviner.

2. Infrared Goniometer Design

The goniometer has been designed and constructed (Figure 1) and is presently being calibrated using a certified spectralon target in the visible and near infrared for reflectance measurements. In the future the goniometer will make combined emission and reflectance measurements in the TIR and FIR surrounded by a cold shield (< 150 K) inside a vacuum chamber (< 10^{-4} mbar) (Figure 2). The physical design of the goniometer is described below:

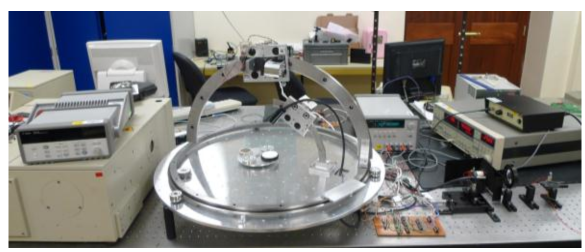

Figure 1: Photograph of the goniometer setup on the optical bench.

2.1 Light Source

For reflectance only measurements the goniometer currently uses a high temperature 45W quartz halogen bulb and reflector to provide a geometrically well-controlled light source. The light source is chopped and coupled to an optical fibre light guide. The output beam from the optical fibre is then collimated onto the sample. For combined emission and reflectance measurements the light source will not be coupled down an optical fibre, but will instead be collimated directly onto the sample.

2.1 Radiometer

For testing and calibration in the visible the radiometer uses a visible SI PiN photodiode detector. For measurements in the infrared, the radiometer uses a high performance pyro-electric detector (Infratec LIE-312F) with a reference chopper for emission measurements and views of a calibrated blackbody target. Initial wavelength selection will be provided by spare Diviner filters [4].

2.1 Mechanical Implementation

Stepper motors are used to control the position of the radiometer's azimuthal and emission angles, and the position of the light source (i.e. incidence angle). A stepper motor is also used to control the sample changer, which can hold up to four samples, one of which is a calibrated blackbody target. A PC is used to control all the stepper motors and to monitor temperatures within the instrument.

Table 1: Angular range of the SEG, which is similar to other goniometers [5].

Angle	Range
Incidence angle	0-74
Emission angle	0-84
Azimuth angle	0-180
Angular accuracy	0.1

2.1 Vacuum Chamber and Cold Shield

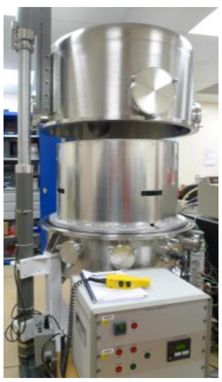

Figure 2: Photograph of the cold shield inside the vacuum chamber.

For measurements in the TIR the level of background thermal radiation must be reduced. Therefore, the goniometer must be surrounded by a cold shield (<150 K). To cool the cold shield to such low temperatures, the whole system must be enclosed in a (<10^{-4} mbar) vacuum chamber (Figure 2). The cold shield is made from 5mm aluminum alloy, and has a diameter of 0.8m and height of 0.5m. Critical components will also be coated in high-emissivity paint (e.g. NEXTEL Black velvet) to prevent stray light reflections from affecting the measurements.

As well as reducing the background TIR radiation, the cold shield and vacuum chamber will provide a lunar like environment around the sample. This simulated lunar environment induces a thermal gradient across the sample, which may affect the scattering properties of the lunar soil [7].

6. Summary and Conclusions

Once operational the goniometer will be able to measure full BRDF of lunar analogue minerals and Apollo samples. This will then allow photometric parameters [e.g. 2] to be fitted to the measurements, creating a new library of BDRF measurements directly comparable to the Diviner dataset.

Acknowledgements

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