

A BRDF MEASUREMENT APPARATUS FOR LAB-BASED SAMPLES. K. Gunderson¹, J. Whitby¹ and N. Thomas¹, ¹Physikalisches Institut, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland; kurt.gunderson@phim.unibe.ch.

Introduction: The intensity distribution of scattered light off of any material's surface, whether that surface is a planetary regolith layer or otherwise, is rarely isotropic. For example, illuminated portions of the Moon exhibit an apparent increase in brightness as phase angle decreases [1]. Such opposition effects generally are attributed to the disappearance of large surface grain shadows behind illuminated portions of the grains. This non-Lambertian property demonstrates the dependence of the scattered light distribution, commonly called the bidirectional reflectance distribution function (BRDF), on basic microscopic (or subpixel) physical properties of the scattering surface. Additionally, this dependence suggests that BRDF measurements of planetary surfaces can make valuable contributions to the remote sensing of surface properties.

BRDF models, based on illumination geometry, observation geometry, and scatter surface characteristics, have been constructed [e.g. 2-5] and used to infer surface properties of objects in the solar system [4]. For the Moon, fitted BRDF model parameter values have been shown to be consistent with analogous values that were measured directly in the laboratory using lunar soil samples brought back to Earth, validating the potential accuracy of the BRDF models. However, surface samples for most extra-terrestrial objects are not available for laboratory study. Therefore, the interpretation and validation of BRDF measurements of most extraterrestrial surfaces must be performed via relations of extraterrestrial BRDF measurements to laboratory-based BRDF measurements of terrestrial samples.

Consequently, we are developing an apparatus at the University of Bern, Switzerland, that will be capable of performing BRDF measurements of laboratory sample materials at relatively low cost ($\approx \$20K$), $\approx 2^\circ$ angular resolution, and over a bandpass of 300–1100 nm. In practice, the data taken by this instrument will be referenced to an off-the-shelf, calibrated, white, Lambert surface. Thus the data analysis will provide radiance factors (r_F) and/or radiance coefficients (r_C). A radiance factor is defined as the brightness of a surface illuminated and viewed at arbitrary angles relative to the brightness of a Lambert surface *illuminated normally*, and a radiance coefficient is the brightness of a surface relative to the brightness of a Lambert surface *identically illuminated* [2].

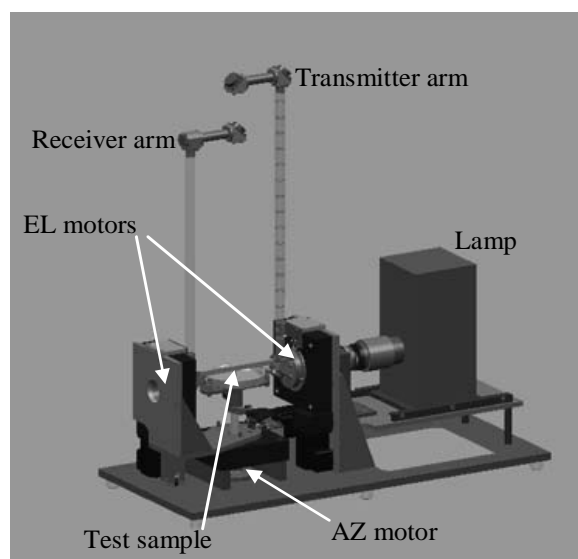


Figure 1. CAD drawing of the goniometer. Both arms in the drawing are positioned at $EL=90^\circ$.

A brief description of the instrument, hereafter referred to as a goniometer, will be described briefly in this abstract.

The light path: The goniometer, depicted in Figure 1, has been designed to provide scatter efficiency data as a function of wavelength, illumination source incidence angle, and observation angles using a light beam with a 1.5 degree full-cone footprint. A quartz tungsten halogen lamp with collimating optics, drawn in Figure 1 as its rectangular housing will appear after assembly, creates the 25 mm diameter emerging beam. The pseudo-continuum emission from the lamp passes through an exchangeable color filter and a beam chopper into the transmitter arm of the apparatus. Within the transmitter arm, three flat mirrors guide the chopped and filtered beam through collimating and light baffling pupils onto the horizontal test sample target. A stepper motor can rotate the transmitter arm around a single axis through a $0-180^\circ$ range of incident elevation angles (EL_i), where 90° is the zenith position. After light scatters from a sample's surface, a portion of the incident radiation enters the receiver arm and is guided by flat mirrors through an adjustable field-of-view restricting pupil and onto a PIN (positive-intrinsic-negative) photodiode. Two stepper motors can orient the receiver arm to collect scattered light at a

selected receiver elevation angle (EL_r) and receiver azimuth angle (AZ_r).

Assuming that the test sample scatters similarly for all AZ_i positions at a given EL_i position, the goniometer permits illumination at all incident geometries. However, if the test sample BRDF is sensitive to the incident AZ_i due to striations, for example, the sample must be manually rotated in its mount in order to illuminate it from varying source AZ positions. Also, because the receiver arm can vignette the illumination source, EL_r must be $>EL_i+2.4^\circ$ or $<EL_i-2.4^\circ$.

Because the portion of the target from which the photodiode can detect light is smaller than the full extent of the illuminated portion of the target, angular resolution of the instrument is limited by a combination of the angular extent of the illuminated portion of the sample that is seen from the photodiode's point of view and the divergence of the illuminating beam. Presuming that the degradation contributions add in quadrature, a 1.5 degree image spot, for example, will provide 1.9 degree resolution. However, the field of view of the photodiode, and therefore the angular resolution of the experiment, can be reduced with an adjustable pupil if sufficient signal-to-noise exists to support it.

Electrical interfaces: An electrical schematic diagram is shown in Figure 3. Analog photodiode output and the analog chopper phase signal are inputted into a lock-in amplifier, which should be able to provide sensitivity over 9 orders of magnitude in dynamic range. All components – motors, lock-in amplifier, chopper, and light source – are equipped with manual controls. However, provisions are being made to interface the lock-in amplifier output and the motor control lines to a PC via RS-232 serial communication lines in order to simplify and possibly automate data acquisition during time-consuming angular scans.

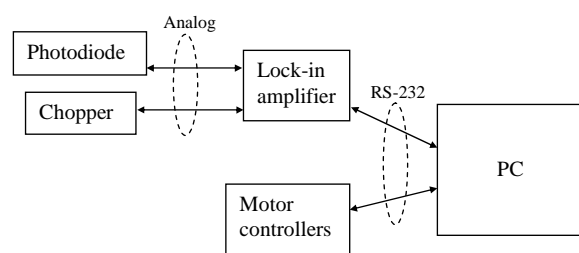


Figure 3. Goniometer electrical interfaces.

Status: The goniometer presented in this abstract is planned for use by undergraduate students as part of their practical course work. At the time of abstract submission, the goniometer optical bench is being fabricated. Motors and the lock-in amplifier have been

delivered, and delivery dates of the remaining components are expected to permit the student-led instrument assembly and operation at the start of the next semester in mid-March 2004. After instrument qualification is verified with a calibrated Lambert surface, planetary analog materials will be tested. These materials might include terrestrial minerals, ices, or possibly meteorites.

References: [1] Gehrels T., *et al.* (1964) *AJ*, 69, 826–852. [2] Hapke B. (1981) *JGR*, 86, 3039–3054. [3] Hapke B. (1984) *Icarus*, 59, 41–59. [4] Hapke B. (1986) *Icarus*, 67, 264–280. [5] Hapke B. (2002) *Icarus*, 157, 523–534.