A GONIOMETER LIGHT SOURCE DESIGN FOR EVALUATING THREE-DIMENSIONAL THERMAL INFRARED EMISSION FROM LUNAR AND ASTEROID ANALOGUE REGOLITH SAMPLES

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Goal

Update the Oxford Space Environment Goniometer (OSEG) to include a realistic treatment of scattering across visible to infrared wavelengths using a light source in order to measure the directional anisotropic re-radiation for airless body samples with varying illumination angles.

1. Background

Analysis of the topmost layer of the lunar surface (≤ 100 μm) can provide clues to the history of the Moon and of the other airless bodies in the Solar System.

Current thermophysical models do not match measurements (see Fig.1):

- → Controlled laboratory measurements at different emission angles under airless body conditions needed to create an accurate three-dimensional thermophysical model.
- → Model will help infer surface properties of the Moon and other airless bodies.

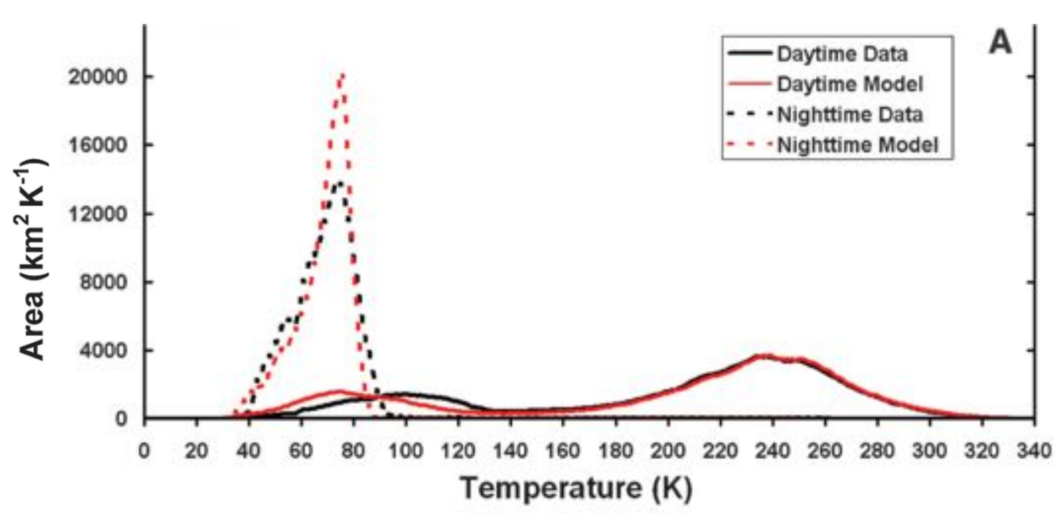

Fig 1: Normalized histograms of measured daytime and night-time bolometric brightness temperatures for lunar regolith [1].

Previous design with hot plate showed samples radiate in the Thermal Infrared (TIR) anisotropically [2].

4. Light Source

The objective was to create a light source to provide solar-like radiation. Requirements:

- ✳ Radiation peaking at approx. 500 nm
- ✳ Collimated rays
- ✳ Powerful
- ✳ Compact
- ✳ Wide beam (50mm across)
- ✳ Uniform with less than 1.5% deviation over desired region

Figure 4: Photograph of light source. It is also fit with a cooling device to prevent the system from overheating.

Solution:
100W incandescent light bulb fixed to a semi-opaque convex lens (B270 Optical Crown Glass) (see Fig. 4)

The output of the designed light source does not meet uniformity requirement (see Fig. 5):

- → Further work on design required
- → Alternative: demonstrate sufficient stability to allow the non-uniformity of the light source to be removed as part of the instrument's calibration scheme

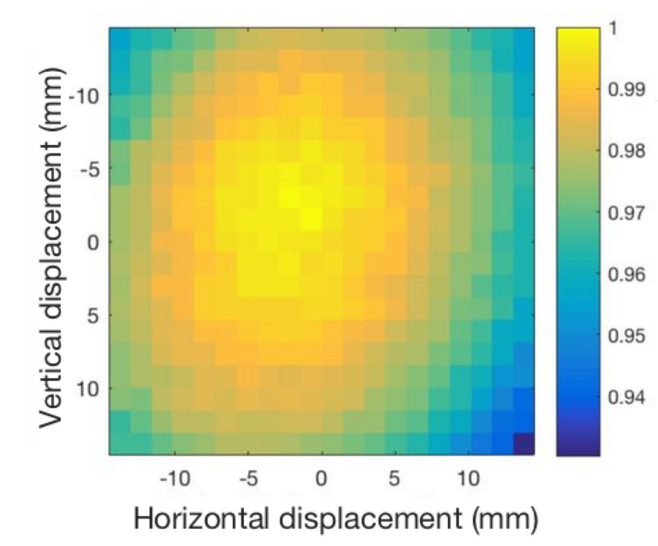

Figure 5: Field of incidence of the light source. SiPiN photodiode (without a lock-in amplifier) sensitive across wavelengths from 0.4 – 1.1 μm showed the light source to be uniform within 5% over the region of interest (disc of radius 12mm).

2. Design

- ✳ Recreates a space environment using a vacuum chamber and a cold shield.
- ✳ Allows phase function measurements of powdered airless bodies regolith simulant samples to be made from the visible to the TIR.
- ✳ Uses a radiometer carriage to move around the sample to measure emission/reflection angles (0 –75 ° from azimuth).
- ✳ Applies a light source to heat the samples and thus produce TIR radiation (see Fig.2).

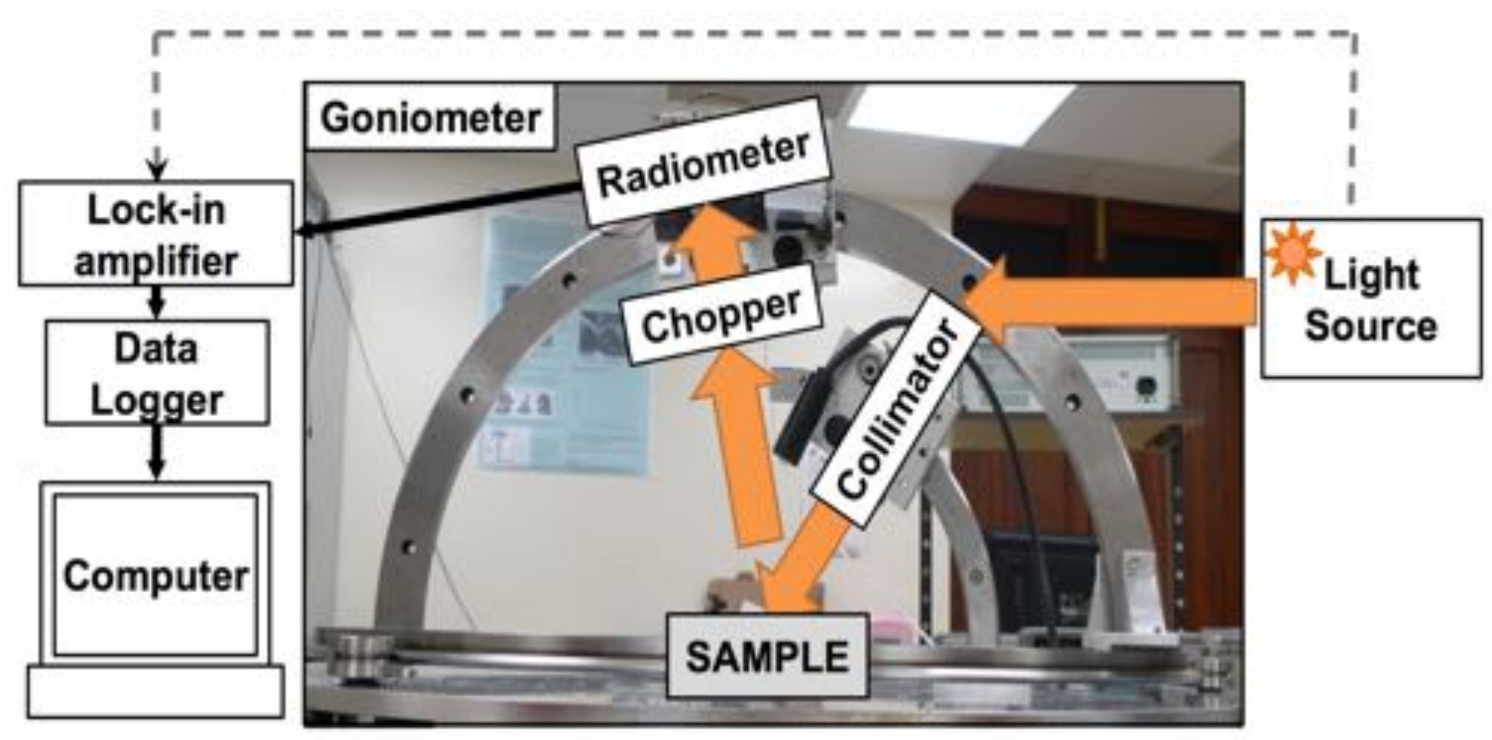

Figure 2: Annotated experimental setup where a sample is being illuminated by the designed light source. A goniometer is a 3D protractor, used in this project to measure how light is scattered from a surface at all possible scattering angles.

5. Translation Stage

A custom two axis automated linear translation stage:

- ✳ performed FOV and beam uniformity measurements.
- ✳ automated using stepper motors.
- ✳ step sizes as small (4.0±0.1)μm

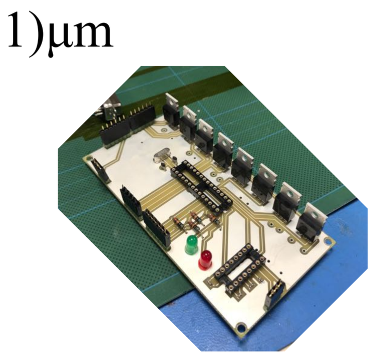

Figure 6: Photograph of the bespoke electronic interface for custom two-axis automated linear translation stage.

3. Infrared radiometer carriage

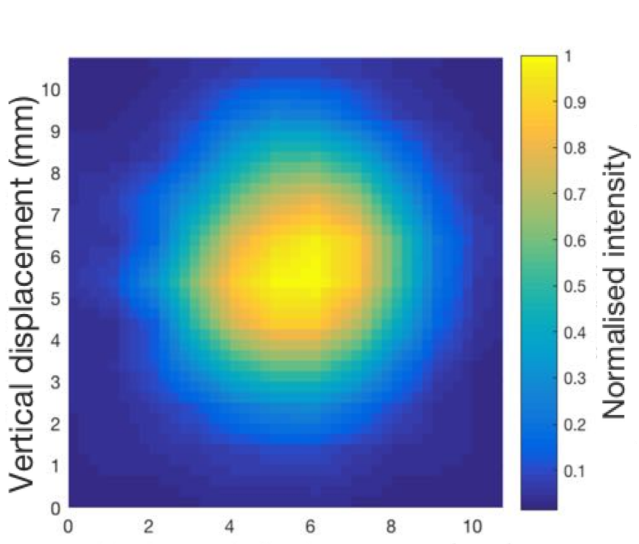

Figure 3: Radiometer field of view. For these measurements, baffles in the optical setup could be adjusted or added to create the optimal field of view for measuring the emissivity of the samples.

- ✳ Several baffles to remove off-axis rays
- ✳ Aluminium mirror
- ✳ TIR pyroelectric detector
- ✳ Reference chopper

The field of view (FOV) measurement of the radiometer was performed (see Fig. 3):

- ○ At 0° a perfect circle is desired to make measurements without correction factors.
- ○ Ensures that the area of the field of view (even at max emission angle) does not go beyond that of the sample.

6. Looking forward…

- ✳ The OSEG is now ready to measure the angular re-radiation of our powdered samples using the newly developed solar illumination light source.
- ✳ The angular re-radiation measurements can be fed back into 3D thermophysical models to improve their accuracy.
- ✳ These can be directly compared to off-nadir measurements made by Diviner, Hyabusa-2 and OSIRIS-Rex to directly infer the surface roughness and composition of the surface regolith of airless bodies [3][4].

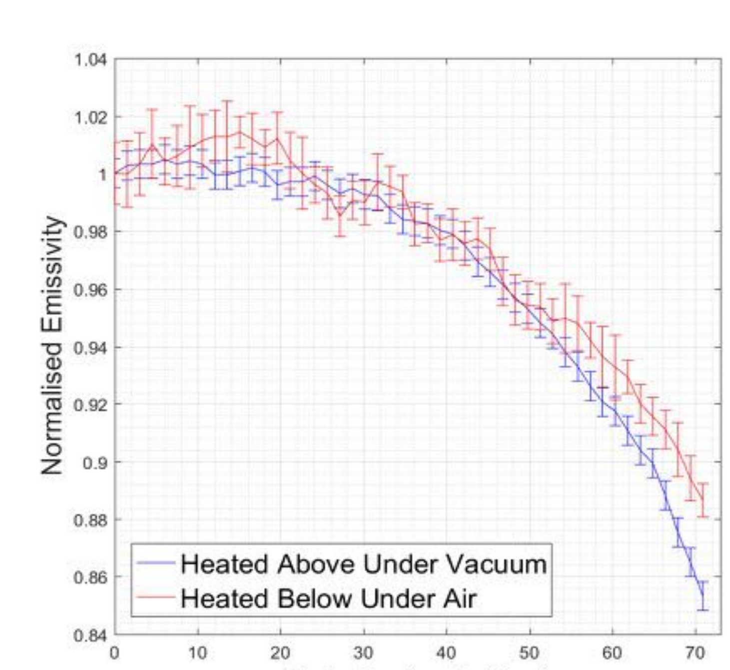

Figure 7: Preliminary phase function measurement for new goniometer design compared with data from previous setup.

- ✳ New light source using LEDs meets the same requirements but does not overheat. Preliminary results are shown in Fig 7.

References: [1] Paige, D. A. et al. (2010). Science, 330(6003), 479-482. [2] Warren, T. J. et al. (2017) Review of Scientific Instruments, 88(12), 124502. [3] Maturilli, A. et al. (2016). Earth, Planets and Space, 68(1), 113. [4] Takita, J. et al (2017). Space Science Reviews, 1-29.