OPTICAL DESIGN OF OPRA: OPTICAL PROBE FOR REGOLITH ANALYSIS. Robert Pilgrim[1], Richard Ulrich[1,2], Matt Leftwich[3], [1]Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR 72701, [2]Department of Chemical Engineering, [3]Space Photonics Inc. Contact: rulrich@uark.edu

Introduction: The Optical Probe for Regolith Analysis (OPRA) will consist of a spike-shaped surface probe delivered to a planet, asteroid, or cometary body by a lander and/or rover. OPRA will have a series of windows along its length, each one having a direct interface to an infrared spectrometer unit housed in the spacecraft's body via space qualified fiber optic cables. Each window will be the termination of two fibers, one for illumination and one for return of reflected light to the infrared spectrometer. Once inserted into the surface, the spectrometer will perform spectroscopy on the material adjacent to each of OPRA's windows, allowing the return of compositional data from a series of depths below the surface. This analysis will be performed with minimal disturbance. For instance, since the spectrometer's electronics are located in the lander's body, the spike will have no active sources of heat, enabling the study of subsurface ices without melting.

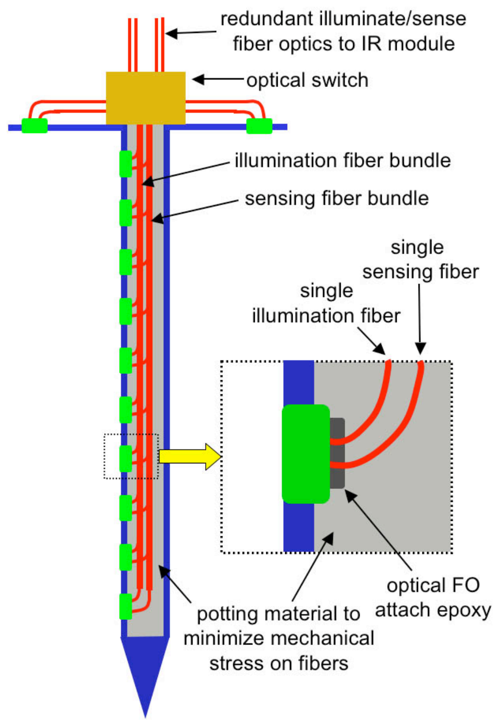

Figure 1. Schematic cross-section of an OPRA probe showing the configuration of the fiber optics and windows. The length/diameter ratio is typical, but actual dimensions depend on the specific mission.

The wavelength range will be 0.8 – 5 microns in order to return the maximum amount of useful geological data from purely reflective spectra [1 - 3]. Table 1 shows the spectral ranges of various other exploratory spacecraft. Wavelengths in excess of a few microns are for emission spectra, which OPRA will not be designed to sense. Unlike these instruments, OPRA will carry its own illumination instead of using solar radiation and will see below the surface.

Table 1. Spectral ranges for various spacecraft designed for geological characterization of planetary surfaces.

Instrument	Spacecraft	Range (μm)
VIMS	Cassini	0.3 to 5.1
NIMS	Galileo	0.7 to 5.2
NIRS	Hayabusa	0.8 to 2.0
Mini-TES	Mars Exploration Rovers	5 to 29
OMEGA	Mars Express	0.5 to 5.2
TES	Mars Global Surveyor	6 to 50
THEMIS	Mars Odyssey	2.5 to 50
NIS	NEAR	0.8 to 2.6
ASTER	Terra	0.5 to 11

Probe Diameter Tradeoffs: Smaller and lighter is desirable for almost all spaceflight hardware but various design tradeoffs will constrain the final size, aspect ratios and mass. For instance, with OPRA a smaller cross section area reduces the insertion force required to drive the windows below the surface. However, the fiber optic cables that will connect the probe to the spacecraft body enter OPRA through the top of the spike and must negotiate a 90 degree turn at some point in order to properly interface the windows in the manner shown in Figure 2. Decreasing the cross section area decreases the required bend radius, possibly leading to loss of signal strength and lowered fiber mechanical reliability. Light loss would be due to the change in internal grazing angle at the bend, but is expected to be less important for an analog application such as this compared to digital signal transmission. The spectrometer's integration time can be increased to compensate to some extent.

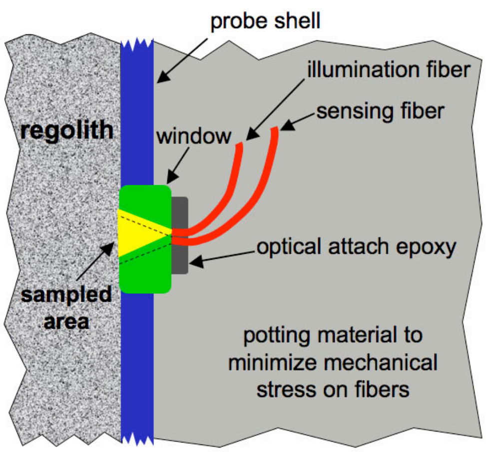

Figure 2. The send and receive fibers will be coupled to the regolith through a quartz or sapphire window. The window may be curved to act as a lens so that the illuminated and sensed areas will overlap as much as possible.

The purpose of this part of the overall OPRA project is to reconcile the optical design with a concurrent project involving the probe's mechanical design. This latter project is also being presented at this conference ("Penetration Testing of the OPRA Regolith Penetrator") and is mainly concerned with the forces required for penetrator insertion and withdrawal along with minimum specifications for wall thickness. The results of both projects will be considered in late Spring 2008 to select a final size and shape of the penetrator.

Optical Design Considerations: There are two main areas for the work reported here: effect of bend radius on signal strength and the proper interface of the fibers with the windows.

An optical intensity sensor is being used to measure the light loss as a function of bend radius for a variety of fiber materials and diameters. The result of these experiments will be to tell us a minimum dimension, at least in one direction, for the interior of the probe so that the 90° bend can be accommodated. It is possible that the shape of the probe can be chosen to house the bend in one dimension, leaving the other one free to be much smaller. Using such a strategy, the cross sectional shape could be a narrow rectangle rather than a regular shape such as a circle or a square. The windows would go in the narrow edge and the fiber could bend along the long dimension. In anticipation of this possibility, this type of shape will be fabricated for penetration testing to see if the required forces are similar to that of more equally-sided shapes.

The design of the windows and fiber attach to the windows is a considerably more complex task. The connection must be robust against temperature cycling and vibration (launch and landing) and must exhibit very low optical losses. The window itself must shepherd the illumination from one fiber onto a large enough area on the regolith to provide a representative sample of what's outside the window. This area should encompass at least ten times the average grain size of the material under study. The same window/lens must then gather as many of these reflected photons as possible in to the sensing fiber for return to the instrument. The fiber length is so short that length losses are probably insignificant.

A wavefront sensor is being used to map out the illumination pattern using several different configurations and shapes of windows from strongly convex to strongly concave. The same lens should serve both purposes since the illumination light is traveling one way and needs to be spread out while the reflected light is traveling the opposite direction and needs to be concentrated.

A central question to be answered is whether or not a single fiber can be used for illumination and sensing as opposed to a fiber bundle. It may turn out that one fiber can be used for illumination since there are few size constraints to the fiber entrance up in the spectrometer unit, located in the spacecraft body. After reflectance from regolith materials that may have albedos less than 10%, there may be a need for multiple fibers on the return leg.

Conclusions: Experiments so far show that bend radius is more of a limiting factor for mechanical considerations of reliability and fiber breakage and it is for signal loss. Initial work with single fibers and various lenses are encouraging. Sufficient refection from ground basaltic samples indicate that analysis might be possible with single fibers both ways. Testing a matrix of lens configurations is underway to determine the optical attach and window shape.

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