SUBSURFACE SPECTROSCOPIC PROBE FOR REGOLITH ANALYSIS.

R. Pilgrim[1], R. Ulrich[1,2], M. Leftwich[3],
[1]Arkansas Center for Space and Planetary Sciences University of Arkansas, Fayetteville, AR 72701, (rpilgrim@uark.edu), [2]Department of Chemical Engineering, [3]Space Photonics Inc.

Introduction: We are designing and testing a subsurface probe as part of NASA's Planetary Instrumentation Definition and Development Program 2007 (PIDD) [1] in collaboration with Space Photonics Inc. [2], our industrial partner on this project. OPRA (Optical Probe for Regolith Analysis) will be able to perform spectroscopic analysis of a planetary body's subsurface without the need to excavate material, thus preserving any laying structure and ices that may be present.

Description: The probe housing will be a thin, hollow titanium spike-like structure with a diameter of approximately 10-15 mm and a length of up to ½ m. The probe can easily be manufactured in different lengths and will be dependant upon the desired depth we wish to extend into the subsurface. The probe will be pushed into the subsurface via a driving mechanism in the deploying lander or rover. Space qualified fiber optic cables will run inside the probe housing, and will connect each window directly to the FTIR. This direct connection will allow spectroscopic analysis through multiple windows, and the corresponding subsurface depths, without the need to move the probe once it is fully inserted into the regolith. Figure 1 shows a single, downward facing window which is being used to evaluate optimum fiber optic arrays and fiber diameters of the transmitting and receiving fibers.

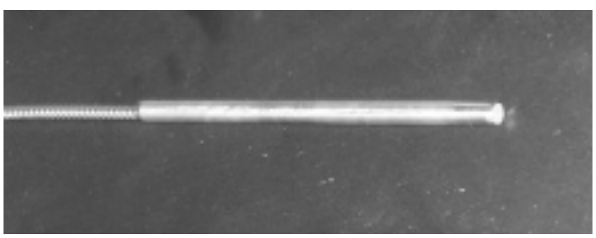

Figure 1. A single, downward looking window used to attain spectra and test various probe configurations.

Fiber Optics: Common silica fibers are only able to transmit up to around 2.5 microns before significant signal degradation occurs. In order to reach 5 microns, we are currently testing a relatively new type of silica fiber doped with fluoride that is being provided by IRPhotonics [3] These fibers are currently under investigation with regard to their suitability for this type of application. A critical aspect of this project is the fiber array configuration and the fiber probe-window interface. We have optimized the array configuration and also optimized the diameter ratios of the transmitting and receiving fibers based on available fiber specs.

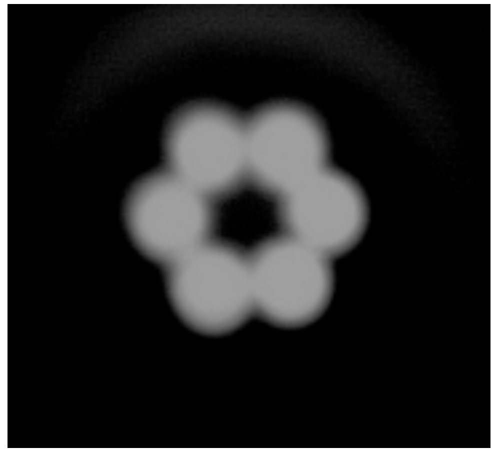

Figure 2. Contact image of six 600 micron fibers transmitting the FTIR signal which surrounds the central 600 micron receiving fiber (not illuminated)

Performance: Probe performance is being optimized on several levels. Firstly, optimization of the efficiency of send/receive ratio of the FTIR signal is being achieved by investigating various fiber configurations and diameters. Figure 2 shows a contact image of a tested configuration with fiber cores of diameter 600 microns . We see six transmitting fibers surrounding a single, central, receiving fiber which unlit in this image. Secondly, as expected, the cross sectional area of the probe will directly affect the amount of force needed to penetrate the probe into the regolith and below the subsurface. We are miniaturizing this cross sectional area via a number of methods and current estimates place the final probe diameter at around 15 mm. The smaller the diameter the less force will be needed by the deploying spacecraft to successfully penetrate into the surface.

Results: By careful selection of fiber optic cable specs, epoxy material, window material/thickness and fiber optic array configuration we are providing an almost seamless transition from the FTIR to the material of interest below the surface. A single side looking window has already been tested and demonstrated to be viable, and we are currently integrating many windows into a single probe as shown in Figure 3. Once the final probe housing configuration has been decided upon, in depth penetration force analysis will be conducted over a wide range of materials such as JSC Mars 1 and icy/rocky materials. The current optimized fiber optic array configuration returns around 200% of the minimum signal needed for the FTIR to produce a valid spectra.

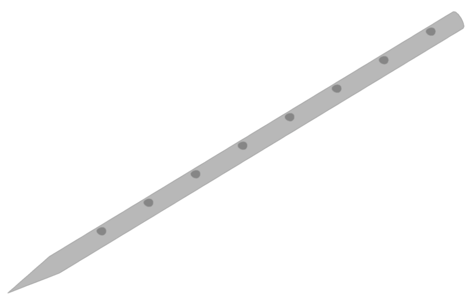

Figure 3. Multiple windows running along the shaft allow spectroscopic analysis as a function of depth

Figure 4. The Andromeda planetary simulation chamber will be used to test the probe in a space like environment, and perform in situ spectroscopic analysis of samples in the chamber

OPRA knowledge and hardware is being adapted to allow spectroscopic analysis of materials in our Andromeda planetary simulation chamber. Figure 4 Also this chamber serves as an ideal environment in which to test the probe in a more realistic situation to those found on other planets. The spectral range was selected to allow investigation of some of the most common elements on Mars, as shown in Figure 5.

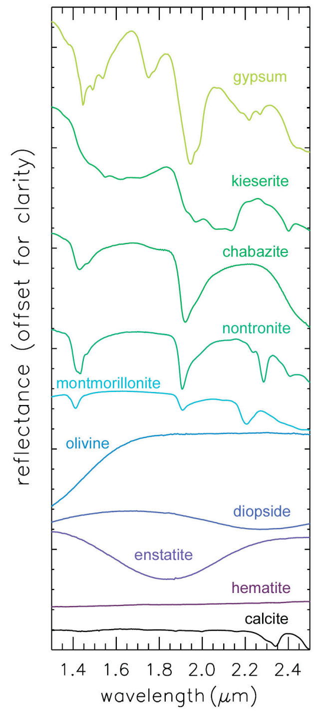

Figure 5. The spectral band for OPRA was chosen to maximize sensitivity to anticipated minerals as well as ices of water, methane, and CO_2.

Conclusion: A robust, versatile low maintenance subsurface probe is being developed and miniaturized to an estimated final diameter of 15 mm. It will have a spectral range from 0.8-5 microns and the length, window spacing and total number of windows can be custom configured and manufactured to any design the user requires with a minimum amount of effort

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References:

1 http://nasascience.nasa.gov/glossary/piddp
2 www.spacephotonics.com
3 www.irphotonics.com