

A MINIATURIZED NEAR INFRARED INSTRUMENT FOR DETECTING H₂O/OH, SULFATES, CARBONATES AND ORGANIC SPECIES DURING PLANETARY SURFACE EXPLORATIONS.

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Introduction: H₂O/OH bearing species (e.g. phyllosilicates, hydrated sulfates, and carbonates) are all important secondary mineral species that can provide information for the evolution history of planetary bodies. It is critical to identify them *in situ* as well as by orbital remote sensing.

Through orbital remote sensing, widespread phyllosilicates (mainly smectite) were discovered on Mars within the Noachian-aged terrains, whereas hydrated sulfates were found mostly within Hesperian-aged terrains^[1]. Carbonates were found co-existing with olivine-bearing and phyllosilicate-bearing units formed during Noachian and early Hesperian era^[2]. Their identifications by *in situ* measurements in future surface explorations (MSL and ExoMars) will be critical to link their occurrences (in specific mineral assemblages) with local stratigraphic sequences, thus to imply the geological processes and paleoclimatic conditions.

On the Moon, in addition to the well-known enrichment of Water-Equivalent-Hydrogen (WEH) at polar regions, the most recent unambiguous discoveries of water/hydroxyl within the lunar surface regolith and their increased abundance with proximity to the lunar poles^[3,4,5] has emphasized the need for the *in situ* identification and characterization of these materials during future lunar missions.

It has been proposed, based on Earth-based telescopic observations and the study of carbonaceous meteorites, that the C/D type asteroids would have retained the materials of early solar system, including altered silicates and hydrated salts (sulfates, carbonates), as well as carbonaceous and organic species^[6]. The *in situ* identification of these species during a landed mission, similar to Phobos Grunt mission, would provide more detailed information on their evolution history.

We have developed a compact, robust, yet very sensitive NIR spectrometer that can be deployed by a lander or a rover for *in situ* identification of above species during a planetary surface exploration.

The miniaturized WIR (Water IR): We report here the development of an active reflectance NIR spectrometer – work supported by NASA ASTID program. Table 1 lists the basic parameters of current WIR brassboard.

Four characteristics make WIR stands out: (1) A spectral range of 1-5 μm permits WIR to directly detect water in different forms (liquid, ice, or clath-

rates, structural H₂O and OH, and water adsorbed on grain surfaces), carbonates, sulfates, hydrated silicates, as well as C-H & N-H bonds in organic species; (2) Multiple active IR sources are used by WIR, thus the strong reflectance spectra from sample surface will not be influenced by the thermal emission. The spectral data handling is straightforward; (3) WIR can be directly deployed on unprepared samples (photo in Table 1) and make measurements at ~ 2 cm working distance with ~ 1 cm FOV, thus minimizing the influences from intervening gases absorption and dust scattering (problems associated with orbital NIR measurements); (4) The high sensitivity of WIR ensures a measurement can be accomplished within 1s to 2 minutes. Our current brassboard runs on 12V DC power and can send spectral data directly over USB connection.

Table 1. Basic Parameters of WIR

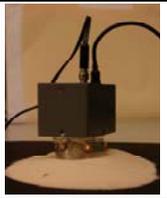
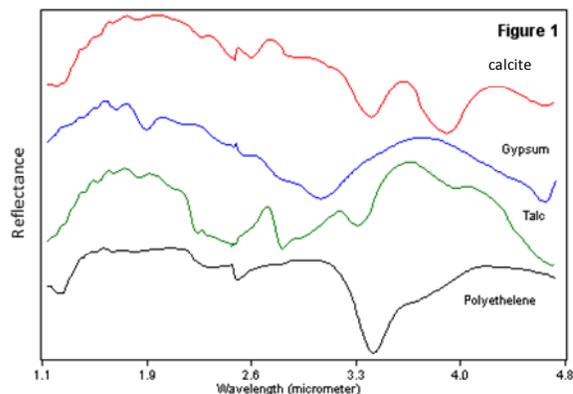
Spectral range	1.14 – 4.76 μm	
Spectral resolution	0.14 nm/pixel	
Average Power	3.3 w	
Mass	294 grams	
Volume	7.5 x7.5 x 5 cm	

Figure 1 shows a set of NIR spectra obtained by the current WIR brassboard. Samples include a phyllosilicate, a hydrated sulfate, a carbonate, and an organic species. The sensitivity test demonstrated that ~ 1 mole % carbonate, 0.5-1 mole% of sulfate, 0.5 -1 mole % of OH-bearing species diluted in a quartz matrix were detectable in a 30 second WIR measurement.



WIR development: The initial *proof of concept study* included the development of a breadboard and a simulation test in laboratory on the detection limits. It was

demonstrated that <1 mole% of OH-bearing species (talc), carbonates (calcite) and hydrated sulfate (gypsum) can be detected from mixtures with quartz^[7].

The brassboard(s) of WIR were developed in three steps (Fig. 2). *WIR-Phase-I* has a size of 10 x 9 x 6.5 cm, a mass of 482 g, and is fitted to a primary Defuse Reflectance Sampling Head (DRSH) for sample illumination and light collection. The WIR-Phase-I covers a spectral range from 2.4 to 4.8 μm with 128 spectral channels. A calcite spectrum with characteristic carbonate overtone bands and sufficient S/N can be obtained in one second^[8].

The *WIR-Phase-II* has a similar size and mass, with an improved illumination and collection DRSH. It covers a spectral range from 1.25 to 2.5 μm with 128 spectral channels. We have taken the WIR-Phase-II on a field expedition to the Tibet Plateau (~3200 meter elevation) in China -- a potential Mars analog site, to study the salt deposits from saline lakes (Fig. 3). We obtained excellent NIR spectra that can be compared with the spectra from orbital remote sensing and the laboratory spectra of collected salt samples. A preliminary cold test (at 4 °C) was also conducted on WIR-Phase-II^[9].

The current brassboard, *WIR-Phase-III* has been further miniaturized to have only 7.5x7.5x5.0 cm in size and 294 g in mass (Fig. 2). In addition, WIR-Phase-III now covers both spectral ranges of *Phase-I* and *Phase-II*, i.e. the full spectrum of 1.14 to 4.76 μm is obtained from a sample in one exposure (Fig. 2). Therefore, WIR Phase III has the equivalent spectral range of OMEGA C and L spectrometers, with comparable spectral resolution and a higher sensitivity.

Deployment of WIR: WIR can be deployed in three different configurations: (1) on the wheels of a planetary rover, for characterizing thousands patches of disturbed soils at close distances (cms). This deployment was named as “Contact Survey”: i.e., the *in situ* measurement ensures high detection of interesting species, while the wheel deployment provides a large number of measurements. A wheel deployment test was carried at Jet Propulsion Laboratory on a spare wheel of Mars Exploration Rover (Fig. 4). (2) By a robotic arm onto selected unprepared targets. For example deployment on a rover or lander for exploring permanently shadowed areas at lunar poles and for detecting the structural form of WEH in lunar regolith. (3) Lastly the WIR can reside as the first screening stage of a rover/lander based laboratory, for pre-evaluation of the samples prepared by SPDS before sending them to other measurement systems, e.g. Raman, XDR/XRF, GC-MS, and life detection chips.

Summary: WIR has two major characteristics; (1) it covers a wide NIR spectral range that contains extremely rich science information and (2) it is very small, light, robust package. We believe it will be a powerful scientific payload in future surface explorations to Mars, Moon, asteroids, and outer planets and their satellites.

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References: [1] Bibring et al., *Science*, 2005; [2] Ehlmann et al., *Science*, 2008; [3] Pieters et al., *Science*, 2009; [4] Sunshine et al., *Science*, 2009; [5] Clark et al., *Science*, 2009; [6] McSween, 1987; [7] Wang et al., *LPSC*, 2004; [8] Freeman et al., *LPSC* 2008; [9] Sobron et al., *LPSC* 2009.

