Revolutionizing IR Spectroscopy in Planetary Science using Photothermal Instrumentation

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Abstract

Here we present a case for using OPTIR in planetary science and for future space missions. We produced laboratory measurements of individual minerals and lunar soil simulants to demonstrate the technique's capabilities. The collected data is correlated with known spectra. Additional spectra previously unmeasured was collected and is presented here.

OPTIR and mIRage

Optical PhotoThermal InfraRed (OPTIR) is a technique that utilizes a dual laser system to achieve FTIR transmission-like spectra. By design, it is a non-destructive, non-contact method of achieving FTIR transmission-like spectra in a refection mode. This method pushes past the spatial resolution limits of traditional IR spectroscopy (~10 – 20 microns) and is governed by the spatial resolution of the visible beam (~.5 microns). Due to these capabilities sample thickness, shape, surface roughness, and size are reduced or non-issues **[1]**.

mIRage is an instrument that utilizes the OPTIR technique described above. Because of this, the instrument can be used to achieve sub-micron spatial resolution measurements and produce transmission-like spectra. The instrument utilizes a tunable pulsing IR laser with varying options of multi-chip QCLs. The second laser is visible probing laser which measures the photothermal effect created on the sample by the pulsing IR laser. mIRage requires little to no sample preparation **[1]**.

Figure 2: Concept image of the mIRage instrument. The laser pathway (covered, on the right) and the optical camera (top, center) are visible in the image. The closed door on the front gives users access to the sample area.

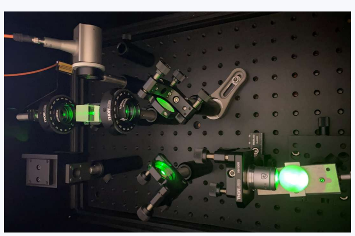

Figure 3: The reduced SWaP O-PTIR prototype will operate in IR absorption mode and in Raman as well – providing dual spectroscopic signatures of materials.

Meteorite and Ice Measurements

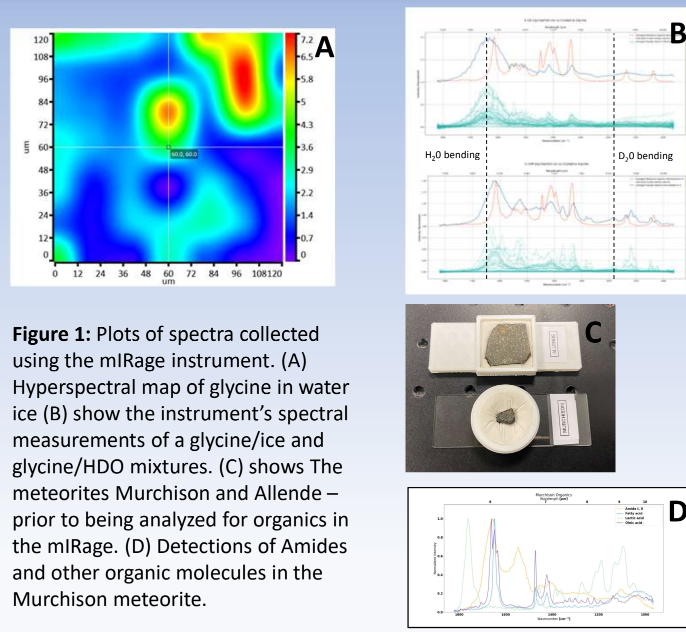

Figure 1: Plots of spectra collected using the mIRage instrument. (A) Hyperspectral map of glycine in water ice (B) show the instrument's spectral measurements of a glycine/ice and glycine/HDO mixtures. (C) shows The meteorites Murchison and Allende – prior to being analyzed for organics in the mIRage. (D) Detections of Amides and other organic molecules in the Murchison meteorite.

Instrument Images

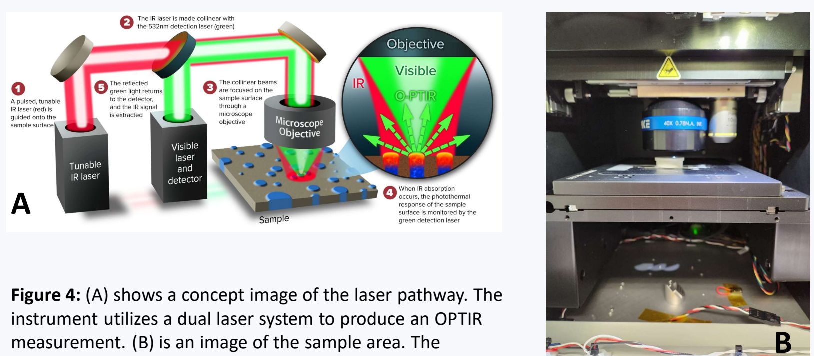

Figure 4: (A) shows a concept image of the laser pathway. The instrument utilizes a dual laser system to produce an OPTIR measurement. (B) is an image of the sample area. The instrument allows movement in three axes. There are two objectives (low and high) allowing for easy detection of areas of interest and providing high spatial resolution measurements.

Experiments and Analysis

The experiments presented here utilize the OPTIR instrument "mIRage". Though sample preparation is unnecessary, the sample examined here were prepared to fit in a 10 mm diameter and 10 mm depth cylindrical sample holder. The granular samples were poured into the sample holder and pressed to form a flat surface of granules. Each sample had a calibration spectra to determine correct instrument settings to increase signal from the instrument. Following the calibration, a large (10s of microns) hyperspectral map was taken of the sample encompassing multiple grains (representing multiple minerals in the case of simulants). The individual spectra from the hyperspectral maps were averaged together to produce what was considered the spectra for the sample. Each sample spectra underwent a normalization (to be more comparable to absorbance features) and a Savitzky-Golay smoothing to yield the final spectra (presented here).

Future Goals

- Catalogue individual minerals
  - Produce publicly available data with consistent available sample information
- Shrinking of instrument for in situ research
- Instrument suites for lander missions
  - In situ analysis of ices in flyby collection missions

Acknowledgements

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References

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[2] Exolith Lab https://exolithsimulants.com/