Non-Destructive Laser-Based Analysis of the Tagish Lake Meteorite In a Controlled Environment for future studies of Asteroid Sample Return Material

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Introduction

As we prepare for asteroid samples to be returned to Earth through missions such as NASA's OSIRIS-REx [1] to asteroid 101955 (Bennu), it is paramount to consider non-destructive laser-based techniques that can detect and identify mineral and organic constituents within sensitive materials while under a controlled environment. Here we present the York University miniature spectroscopic environmental chamber, a new initiative towards preserving sensitive materials, such as pristine Tagish Lake samples, or asteroid sample return materials. The chamber is capable of controlling temperature and pressure conditions to maintain adequate storage conditions of sensitive materials during analyses, and capable of inducing temperature and pressure changes to conduct volatile studies. Spectroscopy techniques include UV (266 nm) Raman and laser-induced fluorescence spectroscopy as well as green (532 nm) Raman spectroscopy to detect and identify geologic and biochemical areas of interest through mapping and point analyses.

Chamber Design

The mini chamber has been built on a table-top bread board along with the laser and optics for spectroscopic techniques through the top sapphire window of the mini chamber. The collection optics include a large (150 mm) telescope to capture as much fluorescence emission and Raman scattering as possible from the window.

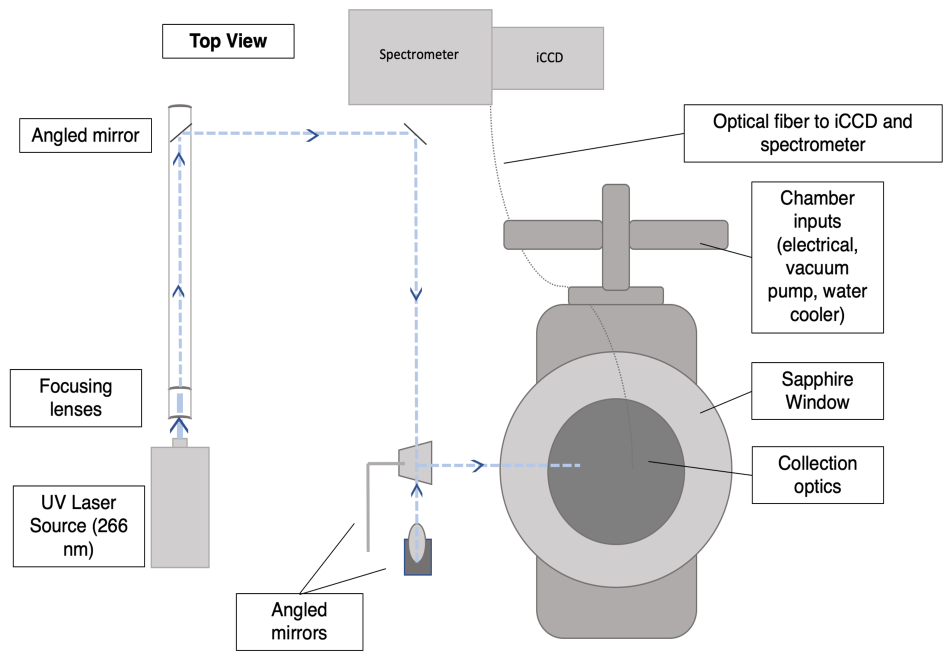

Figure 1: Top-view schematic of current chamber setup and optical path.

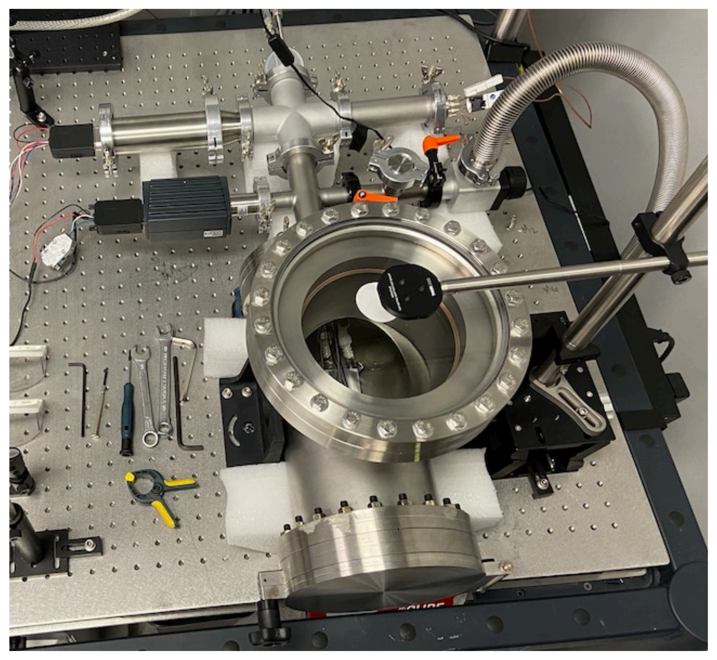

Figure 3: Photograph of chamber setup with sapphire window.

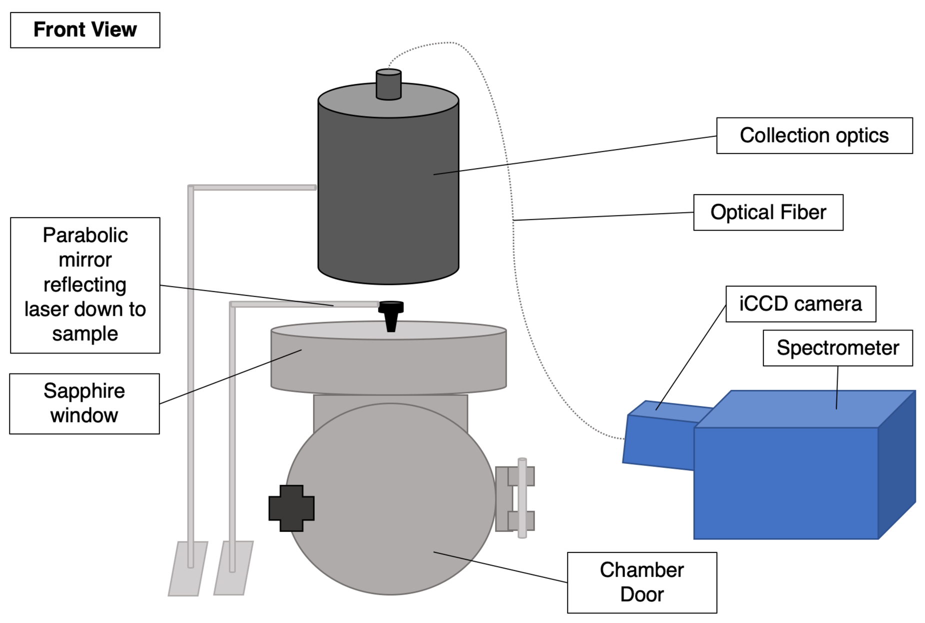

Figure 2: Front-view schematic of current chamber setup with collection optics.

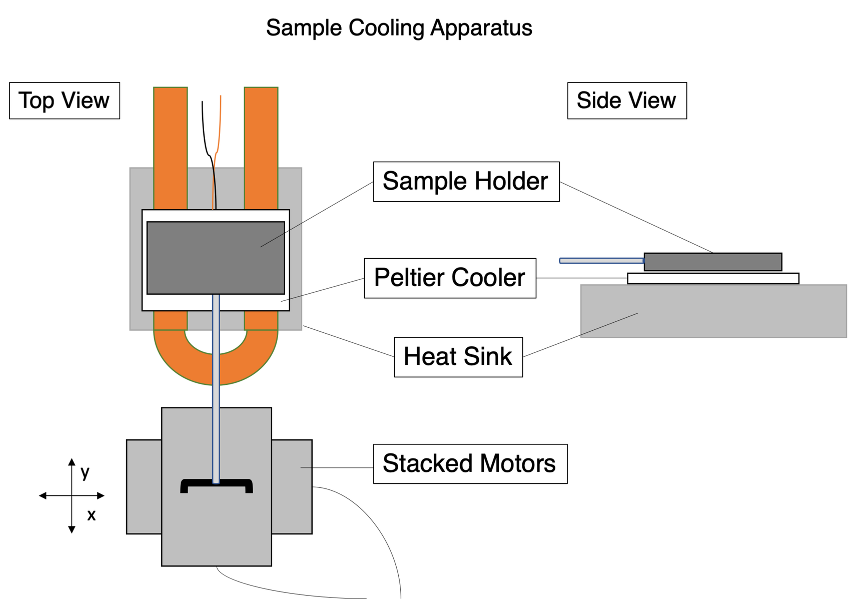

Figure 4: Top and Side view schematic of interior sample cooling apparatus and 2-axis motor for 2D spectral mapping.

Environmental Conditions

Samples, such as pieces of frozen Tagish Lake will be placed onto a temperature-controlled sample holder inside the chamber with a nitrogen gas purge, and then pumped to vacuum conditions when door is closed if necessary for experiment.

The mini chamber at York University can maintain the following conditions:

- < 10^{-4} mbar pressure
- -20 °C temperatures not under vacuum
- Nitrogen Gas purge

Capabilities also include temperature and pressure variation, to allow for volatile experiments. In the future the chamber will be able to hook up with a mass spectrometer to measure volatile off-gassing, as well as measure changes in volatile minerals through spectroscopy.

Spectroscopic Capabilities

The mini chamber will be capable of the following techniques:

UV (266 nm) laser induced fluorescence spectroscopy (LIF)

- Fast mapping technique to detect mineral and organic constituents
- Single acquisition times of a couple seconds
- Time-resolved (TR) fluorescence capabilities with gated iCCD provides more robust identification of organic constituents through calculation of unique fluorescence decay rates

UV (266 nm) Raman Spectroscopy

- Mapping technique with limited fluorescence interference
- Provides good spectral window for minerals and organic materials
- Together with TR-fluorescence, this technique is a powerful tool for geo/biochemical analysis and is a proposed technique for SuperCam and SHERLOC instruments [2], [3]

Green (532 nm) Raman Spectroscopy

- Mapping technique with some fluorescence interference, but better mineral detection
- Good spectral window for mineral identification
- Robust databases of mineral spectra in wavelength

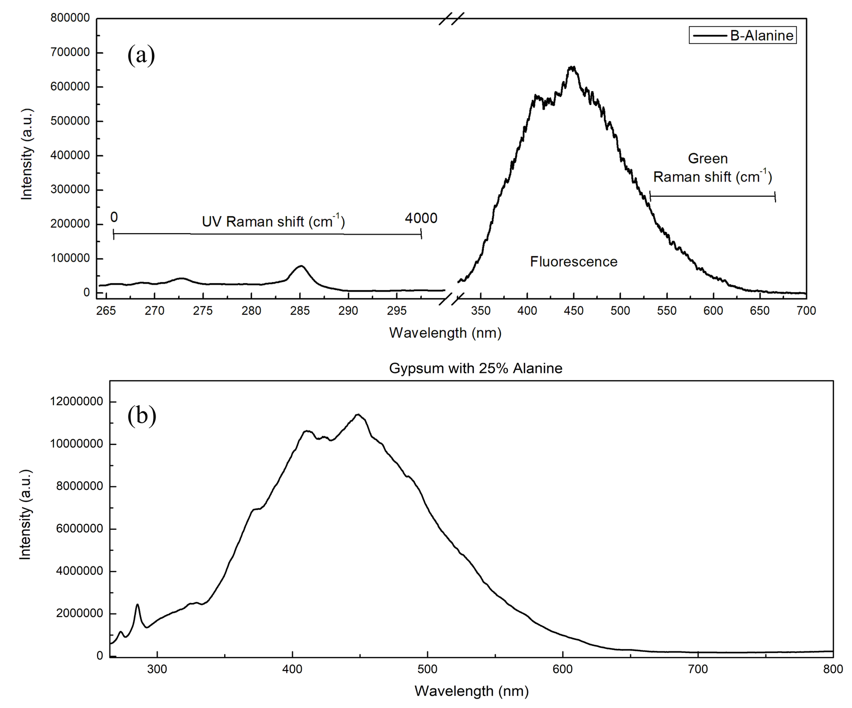

Figure 5: (a) Graphic of spectral ranges available with UV Raman, fluorescence and green Raman using the amino acid Beta-Alanine. (b) UV fluorescence and Raman spectra of 25% Beta-Alanine mix with gypsum.

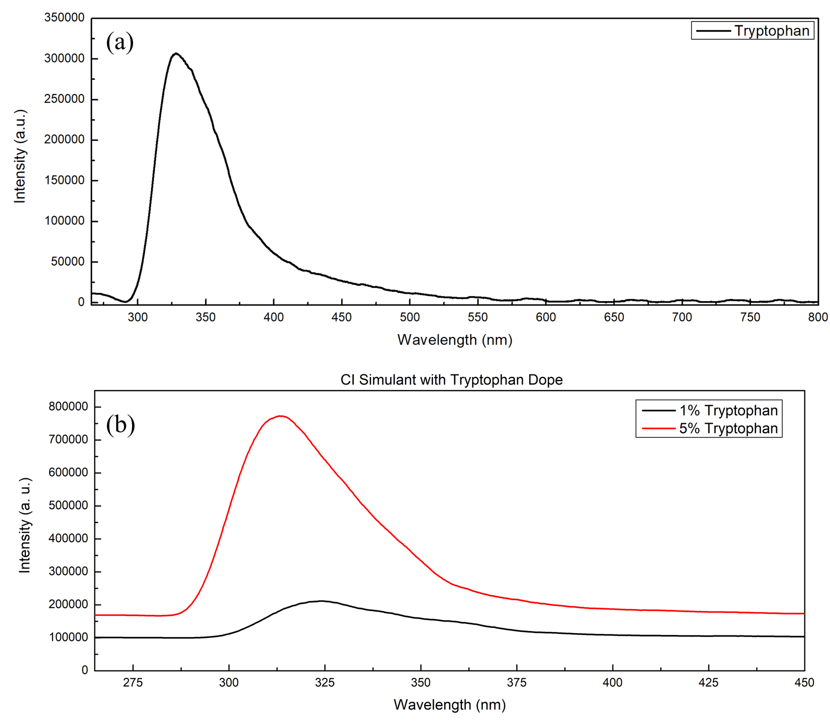

Figure 6: (a) UV fluorescence spectra of pure Tryptophan. (b) UV fluorescence spectra of mixed CI simulant with 1% and 5% Tryptophan.

Future Work

- Spectral mapping and quantification of known concentrations of amino acid mixed with meteorite simulants
- Spectral mapping of features within the Tagish Lake meteorite (pristine samples) under temperature control
- Time-resolved fluorescence and high -resolution spectra of areas of interest in Tagish Lake
- Vacuum and temperature changes to induce volatiles while connected to mass spectrometer.

Acknowledgments

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