Ultra-Compact Raman Spectrometer for Planetary Explorations
Team

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Objective

To develop a compact Raman spectroscopy system with features that will make it suitable for future space missions which require surface landing. Specifically, this system will be appropriate for any mission in which planetary surface samples need to be measured and analyzed.
What is Raman Spectroscopy?

When light hits matter, how does it react?

- Absorbed
- Reflected
- Scattered
What is Raman Spectroscopy?

Scattered Light

- Determined by properties of target
- Unique “fingerprint” for different molecules

- Note: Not all materials create Raman scattered signals
What is Raman Spectroscopy?

Example of photon behavior when hitting polarizable material
What is Raman Spectroscopy?

Example Raman spectra of (a) water, and (b) ice [2]
Recap: Raman Spectroscopy

- Powerful technique for detecting both organic and inorganic materials inside of a sample material
- Uses lasers to excite and vibrate molecules inside of unknown material
- Vibrational pattern of material can be measured to identify molecular composition
Spectrometer

Device that takes in light and disperses it into its component wavelengths

Uses:
- Carbon Dating
- Respiratory gas analysis
- Protein characterization
- Raman Spectroscopy
Realistic Constraints

- Lightweight, small footprint, for installation on planetary rovers
- Ability to measure samples within a range of < 20 cm with no physical samples taken
- Ability to operate in bright light (daytime), and low light (nighttime) environments
- Ability to detect water, biological, and organic compounds
- Ability to detect all minerals, regardless of physical appearance (light / dark)
- Ability to detect Raman signals in the presence of fluorescence
Design Approach

Block diagram of proposed system using a laser, neutral density filter (ND), a 45° mirror (P1), notch filters (NF1, NF2), a 20x magnification microscope objective (20x M), a slit (S1), achromatic lenses (L1, L2) a volume phase holographic grating (HG), and a mini ICCD camera.
Spectrometer

Laser

Nd:YAG (Neodymium-Doped Yttrium Aluminum Garnet; Nd:Y3Al5O12), diode pumped, Q-switched Laser model number QL532-500. Manufactured by Crystal Laser LC, this 532nm 500 mW laser will be operating at a switched rate of 1 kHz.
Spectrometer

ND: Neutral Density Filter

Lowers the intensity of the output laser without affecting the wavelength

Protects back end optics from damage
NF1: Dichroic 532nm Mirror
Reflects 90% of 532nm light while passing other wavelengths

NF2: 532nm Notch Filter
Filters remaining 532nm light
Spectrometer

20x M: Microscope Objective

Intensifies captured Raman signal. Allows the spectrometer to capture and analyze weak signals.
Spectrometer

**S1: 50µm Slit**

Determines the amount of light that is allowed into the spectrometer.
Setting the Slit focal length

Example of (a), incorrect length and (b) correct focal length

(a) Lost signal

(b) Full signal
L1: Focusing Lens

5mm achromatic doublet
1 cm focal length
Maximizes signal intensity into the holographic grating.
HG: Holographic Grating

Transmission grating with angles of incidence and transmission of 45°

Splits incoming light into component wavelengths

2x Fused gratings
Output from grating

Output of grating using all visible light
Spectrometer

**L2: Collection Lens**

- 10mm achromatic doublet
- 3 cm focal length
- Captures light spectrum generated by the holographic grating and directs it into the ICCD
Choosing a collection lens

(a) Reflective grating with 5mm collection lens capturing full spectrum, (b) Transmission grating with 5mm collection lens capturing partial spectrum, and (c) Transmission grating with 1in collection lens capturing full spectrum.
Spectrometer

ICCD
Captures the image from the collection lens and converts it into a digital image
2048 X 2048 pixel resolution
Prototype System

Laser aligned breadboard system
8.79cm x 2.03cm
Prototype System
Engineering Standards

- NASA-STD 8739.6 Implementation Requirements for NASA Workmanship Standards
- IEEE 1394-2008 IEEE Standard for a High-Performance Serial Bus
- ExpressCard 2.0 Standard
References


