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Proposed Hyperspectral Imager for Planetary Surface Missions

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Abstract

This paper introduces a novel hyperspectral camera, SPEC-I, based around a linear variable filter (LVF). The camera has been built, tested and the image processing pipeline created in Aberystwyth University. Presented here are initial results, calibration methods and performance of the camera in the field of planetary sciences.

1. Introduction

Spectral imaging is the combination of the fields of spectroscopy and imaging. Hyperspectral imagers build up sufficient spectral bands to form a contiguous spectrum. The data is stored in a three-dimensional image cube, where each pixel contains a complete spectrum. The dimensions in an image cube represent the traditional x and y dimensions in the two-dimensional spatial frame, with the third dimension, λ, representing the spectral information. [Li et al.]

Hyperspectral imaging was developed initially for remote sensing purposes; this is still it's primary use today [Goetz]. Hyperspectral imagers are used in fields including agriculture and health care, this paper will focus on space applications. On Mars, a rover-mounted camera offers a more compact, robust and practical solution than a conventional diffraction grating system. In that case, the camera must be optimized to offer a resolution on par with an actual spectrometer. The data sets are sent through an imaging processing pipeline on Earth to ensure calibrated data is analysed for the most accurate results.

SPEC-I

The SPEC-I concept is a novel hyperspectral imager being developed in Aberystwyth. Comprised of two LVFs for spectral discrimination, each covering an octave of spectral range. These are fitted in a linear actuator enabling a wide range of detection wavelengths in a small imaging system; SPEC-I covers 400 – 1000nm at a spectral resolution of ~10nm. The spectral range of SPEC-I coupled with fast acquisition times means that it is ideal for a range of applications, including planetary sciences.

The hyperspectral image from SPEC-I can be built up in two ways, by windowing-framing or windowing-pushbroom. The windowing-framing method is achieved by scanning the LVF across the optical path meaning the camera and subject remain tationary. For the windowing-pushbroom method the LVF is fixed over a wavelength range and the hyperspectral data is built up by either moving the camera system or the subject.

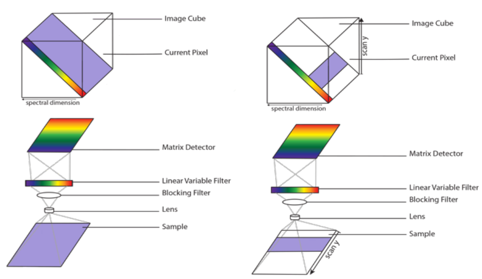

Figure 1: Windowing-Framing and Windowing-Pushbroom Methods – modified from [Li et al.]

SPEC-I has been designed to be applied in a cross-disciplinary manner. The application presented in this paper is the ability of SPEC-I to analyse geological materials, in particular fluorescent minerals that can be indicative of life on other planets. [Barnes et al.]

2. Initial Calibration

Arguably the most important part of spectral imaging development is the calibration of the system. The data from SPEC-I is being calibrated and run through an imaging processing pipeline developed in Aberystwyth University. Presented in Figure 2 is the first step of this process. There may be discrepancies present between the manufacturer stated wavelength positions compared to measured values and these must be found and accounted for prior to data acquisition.

The Aberystwyth Tuneable Light Source (ATLS), which provides a known wavelength of light into an integrating sphere was measured simultaneously by SPEC-I and a reference spectrometer was employed for comparison.

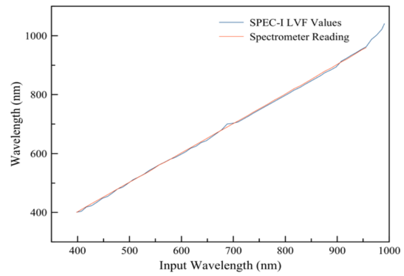

Figure 2: Graph to show offset of LVF wavelength

Figure 2 shows small discrepancies in the measured wavelength compared to the expected wavelengths. This can easily be corrected before image capture by extrapolating data from the graph into the processing pipeline.

3. Preliminary Results

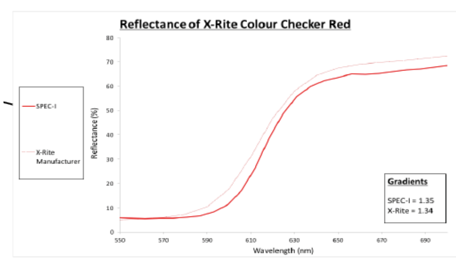

Figure 3: Reflectance Standard Comparison

Initial testing of SPEC-I on reflectance standards has yielded data which aligns with manufacturer reflectance spectra, shown in Figure 3. Curated samples have been used to test the capabilities of SPEC-I as part of a planetary exploration payload. Figure 3 are the results obtained from imaging a sample of Hackmanite under 365nm UV LED excitation.

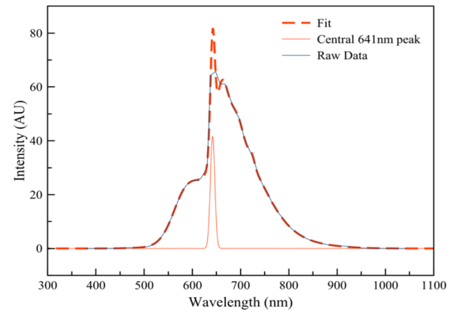

Figure 4: Peak Fitted Hackmanite Spectrum

4. Summary and Conclusions

Figure 3 shows that SPEC-I is capable of producing a spectrum that is clearly representative of the sample and has sufficient resolution to pick out spectral features for identification.

Acknowledgements

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