Compact Thermal Imaging Spectrometer for Planetary Science Applications

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Abstract

NGAS has developed a novel, compact, low weight and power, hyperspectral imaging spectrometer with key features that make it particularly suitable for planetary science: (1) provides hyperspectral measurements anywhere in the 2 μm to 26 μm range, eliminating the need for separate NIR and MWIR instruments; (2) uses a compact optical design resulting in a single compact instrument package; and (3) integrates the sensor and cooling system leading to a low mass and power payload. Hyperspectral imaging spectroscopy has proved to be a key tool in planetary science. This high spectral resolution subset of imaging spectroscopy provides enough spectral resolution to accurately discriminate between observed species whose features overlap in certain wavelength regions. Recent demonstrations of the diagnostic power of such instruments includes the discoveries of hydrated minerals (phyllosilicates) and carbonates on Mars (e.g., Mustard et al. 2008, Ehlman et al. 2008) and water on the Moon (e.g., Pieters et al. 2009). These discoveries have been game-changing in the way we think about these planetary bodies, proving that liquid water was at one time stable on Mars and opening the door for human use of the Moon as a resource for exploration.

The optical design of the NGAS hyperspectral instrument is a custom grating spectrometer with light from a front-end optical telescope imaged onto the spectrometer input slit. The grating is reflective and the spectrometer incorporates both reflective and refractive elements. There is a cold stop located near the FPA to limit thermal background. The overall optical design is an F#3.3 resulting in a diffraction limited blur size of 80 microns at a wavelength of 10 microns. This blur is imaged on a Si:Ga or HgCdTe focal plane array (FPA) with pixel sizes of 20 um to 40 um and 512 x 512 to 1024 x 1024 pixels. The blur is oversampled by 2 to 4 times depending on the pixel size.

The spectrometer has ruggedized construction with lens assemblies built to maintain optics positions following environmental cycling and protect the optics such that there is no risk of fracture due to clamping pressures during cooling. These mounts were designed to withstand

standard launch g-loads, and the entire spectrometer has been successfully put through thermal and vibe testing. On an NGAS internal R&D project, the instrument has been qualified to TRL 6 for space missions.

This spectrometer can be integrated with a wide variety of fore optics depending on imaging range. The exact wavelength range and spectral resolution can be tailored to meet specific missions. For example, two spectrometers can be placed “back to back” to enable dual band imaging on a single FPA, minimizing the size, weight, and power while broadening the wavelength range to maximize science value. In this dual band spectrometer configuration the dimensions are 100 mm x 100 mm x 90 mm. The dual band spectrometer has a mass of less than 2.5 Kg. To achieve the 30K operating temperature required for Si:Ga FPA operation or the 40K temperature required when using a HgCdTe FPA we anticipate using our high reliability pulse-tube Microcooler precooled via a passive radiator to minimize power requirements. Our Microcooler, including drive electronics, has a mass <1Kg and will require power in the 10W to 20 W range.

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