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ASPECT hyperspectral imager for small interplanetary spacecrafts

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Abstract

ASPECT hyperspectral imager is a scalable instrument for small spacecrafts to study composition of planetary surfaces.

1. Introduction

The ASPECT Hyperspectral Imager was originally developed as a payload for ASPECT CubeSat (Asteroid Spectral Imaging Mission) [1] within the ESA-NASA AIDA (Asteroid Impact & Deflection Assessment) project. It is a miniaturized, CubeSat-sized, hyperspectral imager with primary scientific task of high resolution compositional mapping of target surface. Thanks to its modular design, ASPECT hyperspectral imager range and resolution can be easily modified to match specific mission objectives.

2. Scientific and prospecting capabilities

The scientific and prospecting objectives of the instrument are are supported by its VIS-NIR (visual – near-infrared) spectral range. The ASPECT Hyperspectral Imager allows for global compositional mapping and imaging of the target asteroid with sub-meter resolution.

The spectral range of 500-2500 nm covers most common silicate mineral (olivine, pyroxene, and plagioclase) absorption bands related to Fe^{2+} ions in their structure. Additionally, hydrated minerals as serpentine can be detected using ~700 nm Fe^{3+} absorption features. Direct presence of -OH an H_2O can be detected at 1400 and 1900 nm respectively. Observations at various phase angle allows for estimation of surface roughness. An extension of the spectral range into MIR (mid-infrared) region is being currently investigated. This spectral range allows for direct detection of hydrated materials and water/ice in 2700-3000 nm region as well as organic materials at 3200-3600 nm (Fig. 1).

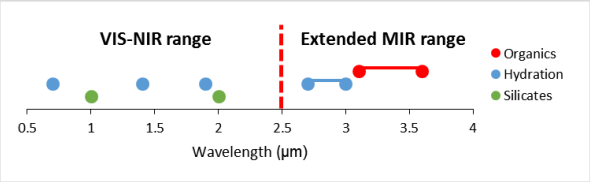

Figure 1: Spectral features detectable with ASPECT hyperspectral imager.

3. Design

The ASPECT Hyperspectral Imager is a miniaturized instrument with range extending from the visible (VIS) up to near-infrared (NIR) wavelengths. In contrast to more traditional spatial scanning imaging spectrometers, the Asteroid Spectral Imager takes 2D snapshots at a given wavelength. When multiple snapshots are combined, a spectral datacube is formed, where the wavelength bands are separated in the time domain. The spectral separation is done by a tunable Fabry-Perot Interferometer (FPI).

The ASPECT asteroid hyperspectral imager is split into three measurement channels, one in the visible (VIS), and two in the infrared (NIR1 and NIR2). The parameters of each channel as well as possible extensions are summarized in Table 1. Sub-meter imager resolution can be achieved at orbital distances of 3 km or lower. All three channels have dedicated FPIs optimized for the desired wavelength range and are independent on each other. The imaged wavelengths are freely selectable within these ranges, and the targeted spectral resolution is 10-50 nm. Recently, a feasibility study of additional MIR

channel with spectral range of 2500-4000 nm was launched. An extension in other direction towards UV (ultraviolet) is also currently under development for ESA ALTIUS and can be potentially integrated into the ASPECT Hyperspectral Imager.

4. Customization

The number of ASPECT imager channels, spectral range and resolution can be customized to meet specific mission objectives. Spectral resolution can be increased using FPI's higher orders of interference. However, this will result in smaller spectral range of the single channel and subsequent need to increase number of the imager channels. For example, improving the spectral resolution from 20 to 10 nm in NIR1 channel, the range will decrease from 900-1400 nm to approx.900-1100 nm. Cascading the FPI will also result in better spectral resolution, however, the throughput and sensitivity will be decreased. Thus, there is a possibility for customization of ASPECT hyperspectral imager configuration satisfy mission requirements.

References

[1] Kohout T. et al.: Feasibility of asteroid exploration using CubeSats – ASPECT case study, Advances in Space Research, http://dx.doi.org/10.1016/j.asr.2017.07.036, in press, 2017.

Table 1: ASPECT Hyperspectral Imager configuration with optional extensions.

Range	VIS	NIR1	NIR2	UV (optional)	VIS (optional)	MIR (optional)	VNIR mini
Size	0.5U	0.5U	0.25-0.5U	0.5-1U	0.5U	0.25U	1 cubic inch
FoV [deg]	10 × 10	5.3 × 5.3 10 × 10	5.3 × 5.3	TBD	2.5 × 2.5	TBD	10 × 10
Spectral range [nm]	500-900	900-1600	1600-2500	250 - 400	430-800	2500-4000	500-800 or 700-1000
Image size [px]	1024 × 1024	512 × 512	256 × 256	Single point	2048 × 2048	Single point	512 x 512
Spectral resolution [nm]	10-15 nm	20-40 nm	20-30 nm	< 2.5 nm	< 2.5 nm	30-50	20 nm
TRL	9	7	5	5	8	3	3-4
Flight heritage	Aalto 1 (in orbit, 2017)	Reaktor Hello World (FM delivered, launch 2018)	Under development, prototype in 2018	ESA ALTIUS (under development)	VISION (FM delivered, launch 2019)	Concept	Under development with ESA
Note			2 FPI cascade. With a single FPI the range is 1600 - 2100	4 FPI cascade. Can also be used with imaging detector		2 FPI cascade. With a single FPI the range is 2500 - 3500	Based on MEMS technology