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Performances of Flight Model of NIRS3: the Near Infrared Spectrometer on Hayabusa-2

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Abstract

We report the performance of the Near-Infrared Spectrometer (NIRS3) on Hayabusa-2 confirmed by ground tests using the flight mode. Results of the tests implied that the dark current at the sensor performs sufficient signal-to-noise ratio (SNR) for scientific objectives. The observed spectrum for each sample of minerals and CM-chondrites demonstrated that the derived reflectance is almost the same as that obtained by Fourier-transform infrared (FTIR) spectroscopy.

1. Introduction

NIRS3 is a scientific instrument on Hayabusa-2 that will be launched toward C-type asteroid 1999JU3 in late 2014. It will observe near-infrared spectroscopy to detect especially molecular absorption by hydroxide minerals at 2.7 µm and hydrated minerals at 2.9 to 3.0 µm. We implemented ground performance tests for the NIRS3 flight model before and after environmental tests in July 2013 to April 2014. We examined whether the performance satisfies requirements and collected data for calibration in the tests. We also observed reflected spectra of minerals, CM-chondrites, and calibration plates of MicrOmega [1].

2. Scientific objectives

C-type asteroids are thought to be parent bodies of carbonaceous chondrites (C-chondrites). The D/H and 15N/14N ratios of C-chondrites have almost the same values with the earth and the moon [2], which suggests that C-type asteroids are one of the candidate origins of terrestrial water by delivering volatiles from icy planetesimals to the inner planets [3]. Therefore, it is important to know the status of hydroxide and hydrated minerals on C-type asteroids. However, the relationship between the sub-groups of C-chondrites and the sub-types of C-type asteroids has not been clarified because of the effects of solar radiation and space weathering. Therefore, we will directly observe the surface of the C-type asteroid without the terrestrial atmospheric absorption at 3µm-band using NIRS3. Detection of younger terrain by global mapping of the asteroid and of the ejector of newly created crater by the Small Carry-on Impactor (SCI) [4] will also provide surface spectra relatively less affected by space weathering. To estimate the quantities of hydrated minerals with accuracies of 1-2 wt%, we determined the minimum requirement for the NIRS3 system to have SNR exceeding 50 at 2.6 µm for global mapping. Thus, NIRS3 will shed light on the initial composition, aqueous alternation, thermal metamorphism, and space weathering of the surface of the C-type asteroid.

3. Instrument design

NIRS3 consists of the Spectrometric Unit (NIRS3-S) and Analog Electric Unit (NIRS3-AE), which are connected with a harness cable (NIRS3-HNS) [5]. Table 1 summarizes the properties of NIRS3. NIRS3 has sensitivity at wave length of 1.8 to 3.2 µm. We adopted a new linear-image sensor using an indium arsenide (InAs) photodiode. We also incorporated passive radiator for refrigerating the optical and sensor assemblies to 193 K (-80°C) to reduce thermal noise.

Optics in NIRS3-S includes a baffle, an objective, seven silicon-germanium (SiGe) lenses for collimating and focusing, a slit, and a flat transmission grating. An electromechanically driven shutter is placed in front of the entrance slit to obtain a dark reference. It chops signals to switch light on and off, and thus, eliminate dark-current noise. The chopping frequency is adjusted to 100 Hz ±10% at 193 K and the readout frequency is designed to be about 100 Hz. A flat transmission grating disperses the light toward the focal plane where the sensor is installed. The InAs linear image sensor is installed at the focal plane assembly. It has pixels of 128 channels and the spectral sampling of 18 nm / pixel. The 20 times greater condenser capacity enables establishing high-gain and low-gain modes. NIRS3 sets the integration time to 10, 20, 40, 100, 200, 250, 400, and 600 µs, 1, 1.2, 1.6, 1.8, 2, 2.5, 4, and 10 ms, and a stacking number from 1 to 1024 (2^0 to 2^{10}). The 0.1° field of view corresponds to the spatial sampling of 40 m per spectrum at 20 km in altitude in the home position observation phase. It also corresponds to that of 2 m at 1 km above the surface when Hayabusa-2 observes the SCI crater from the lower altitude.

4. Ground tests

We implemented ground performance tests using the flight model of NIRS3-S and NIRS3-AE. Infrared rays from the black body source are reflected by the sample and two gold mirrors in a vacuum desiccator, and then injected into NIRS3-S which is refrigerated at -60 to -90°C in a vacuum cryostat. The black body source emission is directly injected into NIRS3-S during amplitude-calibration tests. Lights from a halogen lamp are injected into NIRS3-S through a monochromator during frequency-calibration tests. NIRS3-AE controls the inner calibration lamps, the chopper, and data acquisition by the sensor in NIRS3-S. NIRS3-AE is connected to a PC through Space Cube® which is a SpaceWire-based computer simulating the data handling unit and the mission data processor of Hayabusa-2.

Results of flight-model tests implied that the dark current at the InAs sensor is much lower than that of the engineering model [5], which improves SNR. The projected on-board SNR was confirmed to be sufficient during the one-year observation period of 1999JU3 assuming the asteroid surface temperature estimated from the heliocentric range and solar phase angle. The SNR exceeds 300 after 2.5 ms integration and 1024-stacking at the home position observations. It exceeds 60 after 1 ms integration and 64-stacking for the SCI crater observations. The data obtained after the vibration tests and thermal-vacuum tests indicate that NIRS3 is sufficiently durable for the launching and on-orbit environments. The observed spectra for samples of serpentine, olivine, and CM-chondrites such as Murchison, Murray, and Jbilet Winselwan demonstrated that the derived reflectances are almost the same as those obtained by FTIR spectroscopy. These design results show that NIRS3 has sufficient performance for scientific objectives.

Table 1: Properties of NIRS3 instruments

Item	Properties
Aperture	32 mm
Spectral range	1.8-3.2 µm
Pixel number	128ch (linear)
Spectral sampling	18 nm/pixel
Field of view	0.1°
Spatial sampling	40 m/spectrum at 20 km* 2 m/spectrum at 1 km*
Integration time	10 µs - 10 ms
Stacking number	2^0-2^{10} (1-1024)

*) Altitude above the target asteroid surface.

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