CHARACTERISTICS AND CURRENT STATUS OF NEAR INFRARED SPECTROMETER FOR HAYABUSA MISSION. M. Abe[1] , Y. Takagi[2], S. Abe[3], K. Kitazato[1,4], T. Hiroi[5], Y. Ueda[4], F. Vilas[6], B. E. Clark[7], and A. Fujiwara[1], [1]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency(3-1-1 Yoshinodai, Sagamihara-shi, Kanagawa-ken 229-8510, Japan; abe@planeta.sci.isas.ac.jp, Kitazato@planeta.sci.isas.ac.jp, fujiwara@planeta.sci.isas.ac.jp), [2]Toho Gakuen University(3-11 Heiwagaoka, Meito-ku, Nagoya 465-8515, Japan; takagi@toho-jc.ac.jp), [3]Astronomical Institute Academy of Sciences Czech Republic(251 65 Ondrejov, Czech Republic, Europe; avell@asu.cas.cz), [4]University of Tokyo(7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan; yueda@space.eps.s.u-tokyo.ac.jp), [5]Brown University(Providence, RI 02912, USA; takahiro_hiroi@brown.edu), [6]National Aeronautics and Space Administration(Lyndon B. Johnson Space Center, Houston, TX 77058, USA; Faith.Vilas1@jsc.nasa.gov), [7]Ithaca College(267 Center for Natural Sciences Ithaca, NY 14850-7288 USA; bclark@ithaca.edu).

Introduction: NIRS is a near infrared spectrometer on-boarded the spacecraft HAYABUSA (MUSES-C), which aims to return samples from a near-earth asteroid, (25143) Itokawa (1998 SF36). HAYABUSA was successfully launched by Japanese M-V-5 rocket on May 19, 2003. After the earth swing-by in Jun 2004, the spacecraft will arrive at the asteroid in summer 2005. During the rendezvous phase with the asteroid, we will observe the asteroid surface using NIRS and obtain reflectance spectra of the surface materials across the wavelength range of 850nm to 2100nm. Based on ground-based observations [1],[2],[3], (25143) Itokawa appears to be an S(IV) type asteroid. NIRS can detect absorption bands due to olivine and pyroxene and investigate the mineralogical composition of the surface materials. Combining with the data from asteroid multiband imaging camera (AMICA) and X-ray spectrometer (XRS), we can reveal a relationship between asteroids and meteorites.

NIRS's characteristics: NIRS is divided into two components. One is a data processing unit and other is a sensor unit. The former is named as NIRS-E, the latter is named as NIRS-S (cf. Figure 1). NIRS-E is packaged in the NIX-E, which is a common shared package with XRS that consists of an onboard computer and a power supply unit. NIRS-S is attached inside the –Y-panel (one of the side panels of the spacecraft), and the line of sight is approximately turned in the direction of –Z-axis through the hole on the –Z-panel (bottom panel). The weight of NIRS-E is 0.271kg and NIRS-S is 1.534kg. NIRS-S has a length of 336 mm, a width of 165 mm, and a height of 100 mm. The power dissipation of NIRS is 2.45W during the stand-by condition. Maximum power dissipation is 9.5W at maximum drive of the electric cooler. NIRS-S has a 64-channel InGaAs photodiode array as a detector and a grism (grating – prism) system. Spectral resolution is 23.6nm/channel. The second order light is separated from the first order image by a cross disperser attached to the grism. The filed of view is 0.1 x 0.1 degrees. Aperture size of collecting area affected by front hood is 27.2mm of the diameter. NIRS-S has a shutter on the slit between two off-axis parabolic mirrors. The shutter can open and close the slit at a frequency of 7.63Hz. Integration time can be selected from 0.256 msec to 57.344 msec by every 0.256msec. Total F-number of this sensor is 1.0. The operated temperature of the detector sets normally at -15 °C. This temperature is controlled by system heater of the optical bench and electric cooler in the detector. NIRS-S has calibration lamp and LED in order to monitor the variation of the responsivity and relationship between the channel and observed wavelength. We summarize the NIRS's characteristics in Table 1.

NIRS's prelaunch calibration: We measured initial property of NIRS before launch. The relationship between the channel number and wavelength of calibration light was expressed as,

$$L = -23.56\, n + 2271.4,$$

where L is the wavelength in nanometer, n is the channel number counted from 1 to 64. As shown in Figure 2, responsivity at -15 °C is larger than 100 V/(W/m2/sr/nm)/s between 810 nm and 2130nm wavelength (200 at 850nm, 2150 at 1550nm, 1200 at 2050nm, and 600 at 2100 nm). Noise level is about 1mV and gain of the output is 1769DN/V. Dynamic range of the output is 14bit (16383DN). Saturation level of the data is about 1.6V at -10 °C. Dark current of the detector is 17pA that is 3.3V/s as the output voltage at -4 °C. The dark current becomes half value as the detector temperature decreases about 8 °C. Assuming Itokawa's bidirectional reflectance is 0.07, output voltage at observing the asteroid is about 1V at 1500nm for 25.6msec which is a nominal integration time, and we can detect the flux from Itokawa more than 100 of signal to noise ratio for all of observing wavelength range without saturation.

Current status of the cruising phase: After the successfully launch, initial operation of NIRS had been held at May 12 and 16. During initial operation we have checked and confirmed NIRS's function and property. Obtained on-board lamp and LED data agreed with that obtained before the launch. Responsivity and relationship between the channel and observed wavelength had not changed before/after the launch. At May 23 and June 5, we checked and measured co-alignment between the line of sight of NIRS and –Z axis of spacecraft coordination by observing alpha Scorpius. We confirmed that the co-alignment has not changed before/after the launch. From June to December, the spacecraft used ion thruster engines for almost time to put the spacecraft into the earth swing-by orbit. During this period we only obtained lamp and LED data for about once per month to monitor the variation of the responsivity and relationship of the channel and wavelength, except for the chance to observe Mars on November 11 and 18. In this observation, we succeeded at obtaining the reflectance spectrum of the surface material of Mars and detecting the atmospheric CO_2 absorption band. On January 6, 2004, we performed simultaneous observations with NIRS and AMICA, and checked and measured co-alignment between the line of sights of NIRS and AMICA. We are planning to observe the Moon and the Earth at the earth swing-by in June of this year. This is only a chance of the area source observation. Until the arrival at the asteroid, we will perform point source (bright star and planet) observations several times, and monitor the lamp and LED data about once per month.

Observing plan during rendezvous phase: Asteroid (25143) Itokawa is about a 300-m sized body [4],[5],[6]. After arriving at Itokawa, the spacecraft will stay around the home position (HP), which is about 6 km in altitude above the asteroid surface. At the HP, apparent diameter of the asteroid is about 3 degrees, and spatial resolution of NIRS is about 10 m at the asteroid surface. During the HP keeping phase, we will perform global mapping by slewing the spacecraft attitude along the meridian iteratively. Because it has been known that the spin rotation period of Itokawa is about 12 hours[7],[8], if we set 0.025deg/sec of the slewing rate, 4 degrees of the slewing amplitude and 6 minutes of the slewing period, we can make the footprint cover all of the surface. Solar phase angle at the HP is less than 30 degrees all of the time. We will also obtain the reflectance spectrum for high solar phase angle apart from the HP. Combining the result of AMICA and XRS observation we estimate the distribution of the surface material and the physical condition, and then select the sampling point. Before the sampling of the surface material, the spacecraft descends from the HP to the surface. During descending phase, NIRS will also observe the surface include the sampling point more high spatial resolution than that obtained form the HP.

References: [1] Abe M. et al. (2002) *LPS XXXIII*, Abstract #1666. [2]Binzel R. P. et al. (2001) *MAPS*, 36, 1167-1172. [3] Kelley M. S. et al. (2001) *MAPS*, 36, suppl., A95. [4] Ishiguro M. et al. (2003) *PASJ*, 55, 691-699. [5] Ostro S. J. et al. (2001) *BAAS*, 33, 1117. [6] Sekiguchi T. (2003) *A&A*, 397, 325-328. [7] Dermawan B. et al. (2002) *PASJ*, 54, 635-640. [8] Kaasalainen M. et al. (2003) *A&A*, 405, L29-L32.

Table 1. Characteristics of NIRS-S

Spectral range	850-2100nm
Spectral resolution	26nm
Field of view	0.1deg x 0.1deg
Collecting area	560mm^2
Detector array	InGaAs
Number of channel	64
Size of detector element	50um (W) x 100um (H)
Mass	1.534kg

Figure 1. Photograph of NIRS-S

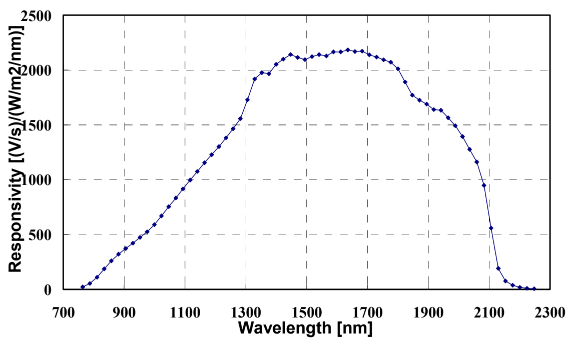

Figure 2. Responsivity of NIRS