**A STUDY OF NEAR-INFRARED HYPERSPECTRAL IMAGING OF MARTIAN MOONS BY NIRS4/MACROMEGA ONBOARD MMX SPACECRAFT.**

T. Iwata[1], T. Sakanoi[2], H. Nakagawa[2], J-P. Bibring[3], V. Hamm[3], C. Pilorget[3], T. Nakamura[2], S. Aoki[4,2], T. M. Sato[2], S. Crites[1], Y. Kasaba[2], T. Imamura[5], and A. Yamazaki[1] [1]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan; iwata.takahiro@jaxa.jp), [2]Tohoku University (Sendai, Japan), [3]Institut d'Astrophysique Spatiale, Université Paris-Sud (Paris, France), [4]Institut d'Aéronomie Spatiale de Belgique (Brussels, Belgium) , [5]University of Tokyo (Tokyo, Japan).

**Introduction:** A new mission to explore Mars and its moons is started to study the migration of primitive material across the snowline in the solar system. The Martian Moons Exploration (MMX) is a probe which will be launched by Japanese launch vehicle H-III and will navigate the quasi satellite orbit of Phobos, and will make fly-by to Deimos. One of the major purposes of the spacecraft is to return rock samples from the surface of Phobos to the Earth so as to distinguish Phobos is composed of primitive volatile-rich material or differentiated Martian material. Therefore, it is important to investigate distribution of hydrated minerals, hydroxide minerals, and organic matters. These scientific requirements make it essential to install the near infrared spectroscope on MMX.

NIRS4/MacrOmega is an imaging spectrometer for the near infrared hyperspectral imaging, which is one of candidates to be installed on MMX spacecraft. It is based on MicrOmega on the ExoMars Rover and Hayabusa2 MASCOT [1]. This paper report the scientific purposes, basic specifications, and operation plans of NIRS4/MacrOmega.

Table 1. Target wavelengths for NIRS4/MacrOmega.

| Main target | λ [μm] |
|---|---|
| Materials on Phobos and Deimos | |
| Hydroxide minerals | 2.7 - 2.8 |
| Hydrated minerals | 3.0 - 3.2 |
| Organics (linear chain structure) | 3.3 - 3.5 |
| Reflective Continuum | 0.9 - 3.6 |
| Radiation (temperature) | 3.2 - 3.6 |
| Atmosphere on Mars | |
| $H_2O$ | 2.50 - 2.65 |
| Pressure ($CO_2$) | 1.90 - 2.20 |
| Dust / aerosol amount ($CO_2$) | 2.65 - 2.90 |
| Dust / aerosol: size and number | 0.90 - 3.60 |
| $O_2$ | 1.27 |
| CO | 2.3 |
| $H_2O$-ice | ~3.5 |

**Scientific Objectives:** NIRS4/MacrOmega can point to the surface of both Phobos and Mars during navigating the quasi satellite orbit of Phobos, and it will point to the surface of Deimos when MMX executes fly-by there. We prepare two major scientific objectives of NIRS4/MacrOmega; 1) materials on Phobos and Deimos, and 2) atmosphere on Mars. Table 1 lists the main targets of observations and their representative wavelengths (λ).

MMX aims to elucidate the evolution of our solar system by investigating the migration process of primitive materials in the early stage. One of the significant subjects to solve is the origin of Martian satellites, which should be judged if they were satellites formed by the giant impact or asteroids captured by Mars. The results will shed light on the process of the formation of terrestrial ocean and life origin materials in it. NIRS4/MacrOmega will observe the absorption by hydroxide or hydrated minerals on Phobos and Deimos in the wavelength of 2.7-3.2 μm. By analyzing the shape of spectra, we will distinguish between water in hydrous silicate minerals, water molecules, and water ice particles. NIRS4/MacrOmega will try to detect the absorption by organic matters in the wavelength of 3.3-3.5 μm.

NIRS4/MacrOmega will also observe the Atmosphere on Mars from the orbit beside Phobos, which can provide a global imaging toward Mars with high temporal resolution. We will derive column density of water vaper and ice cloud by retrieval methods. We will also obtain surface pressure of $CO_2$ and column densities of CO, *etc*. to elucidate water cycle in the Martian environment.

Table 2. Main specifications for NIRS4/MacrOmega.

| Item | Properties |
|---|---|
| spectroscope | AOTF |
| detector | HgCdTe |
| array | 256 x 256 pixels |
| FOV | 6 deg |
| IFOV | $4.1 \times 10^{-4}$ rad |
| f-number | 6 |
| wavelength | 0.9 – 3.6 μm |
| spectral sampling | 20 $cm^{-1}$ |

**Characteristics of Instruments:** NIRS4/ MacrOmega is a hyper-spectral imager with a spectroscopic function by an Acousto-Optic Tunable Filter (AOTF). Table 2 shows the main specifications for the instrument. The spectrometer has an imaging optics with a field-of-view (FOV) of 6 deg and an f-number of 6. The wavelength range is from 0.9 to 3.6 um, which covers molecular absorptions listed in Table 1. It has enough range to estimate reflective continuum for Martian moons, and dust/aerosol sizes and numbers for the Martian atmosphere. The spectral sampling is 20 cm$^{-1}$, which corresponds to the wavelength resolution of 2 nm at 1 μm, 8 nm at 2 μm, and 24 nm at 3.5 μm. Two cross polarizers are used as a light trap to remove the out-of-band lights. The detector is a 2-dimensional HgCdTe array of 256 x 256-pixel which will be installed at the focal plane that will be cooled to 110 K. The FOV of one pixel (IFOV) is 4.1 x 10$^{-4}$ rad, which provides the spatial resolution of about 8 m at the typical observation altitude of 20 km above Phobos. We will adopt scanning mirrors at fore-optics to carry out cross-track FOV tracking for the targets. The signal-to-noise ratio (SNR) will be tuned to be >100-300 by selecting the integration time and observation wavelength.

Table 3. Operation Orbit and Objectives.

| Target and orbit | Main objective |
|---|---|
| Phobos | |
| 100-200 km | Global mapping of Phobos to select prior areas and landing sites |
| ~20 km | Precise mapping for candidate landing sites, precise mapping for selected areas |
| Low | High-resolution observation for selected areas |
| L1, L2-point | Precise observations toward blue and red region [2], calibration for phase angle |
| touch down (20km to 1m) | Precise observations toward sampling sites |
| Deimos | |
| Fly-by | Semi-global mapping of Deimos |
| Martian atmosphere | |
| quasi satellite orbit of Phobos | Global mapping and monitoring to select proper materials and areas |
| | Precise observations toward selected areas, such as Tharsis, Arbia Terra, etc. |

**Observation Plans:** NIRS4/MacrOmega will observe Phobos to survey the sampling site before sampling, to investigate the sampling site precisely at the touch-down mode, and to make global mapping. Mars will be observed in the spare time of staying at Phobos, and Deimos observation will be executed in the fly-by orbit. Table 3 summarizes main observation objectives at each orbit.

Global mapping of Phobos to select prior areas and landing sites will be performed on the quasi satellite orbit at 100 to 200 km in altitude. Precise mapping for candidate landing sites will be followed at about 20 km in altitude. We will also examine the high-resolution observation for selected areas at the orbit lower than 10 km, and precise observations toward blue and red region [2] at the Mars-Phobos Lagrangian points 1 and 2. In the touch down phase, we will observe toward limited area at selected wavelength in the altitude of 20 km to 1 m in altitude at selected wavelength, and examine to observe toward sampling site at full wavelength in the altitude of between 1 km and 1 m.

Observations for Deimos will be basically executed from the fly-by orbit, and they are examined to be made at the near circular orbit. The wavelength will be selected according to the relative velocity to the surface. The requirements for SNR are >300 for the Phobos precise mapping at 20 km, and >100 for other modes to observe Phobos and Deimos.

Observations of Martian atmosphere from Phobos orbit have two main modes: 1) the global mapping, and 2) the local tracking. The requirements for SNR are >300 for both the modes. FOV of 6 deg needs 97 areas to cover global surface. In the global mapping mode, the data from 256 x 256 pixels will be binned and the wavelengths are selected to reduce the total exposure time under the required SNR of >300. In the local tracking mode, the FOV will be fixed to and tracked toward certain points.

**References:** [1] Bibring J-P. et al. (2012) *Proc. 30th ISTS*, 2015-k-14. *In Abstract Asteroids, Comets, Meteors 2012*, #6399. [2] *ex.* Fraeman A. A. et al. (2012) *J. Geophy. Res*, 11, E00J15, 10.1029/ 2012JE004137