MID-INFRARED IMAGER FOR MAPPING THERMAL EMISSION OFF THE SURFACE OF NEAR-EARTH ASTEROID 1999JU3 IN HAYABUSA-2. T. Okada[1], T. Fukuhara[2], R. Nakamura[3], T. Sekiguchi[4], S. Hasegawa[1], K. Kitazato[5], M. Taguchi[6], T. Imamura[1], and Hayabusa-2 Mid-Infrared Imager Team, [1]Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (3-1-1 Yoshinodai, Sagamihara, Chuo-Ku, Kanagawa, 252-5210 Japan, okada@planeta.sci.isas.jaxa.jp), [2]Hokkaido University, [3]National Institute of Advanced Industrial Science and Technology (AIST), [4]Hokkaido University of Education, [5]CAIST, University of Aizu, [6]Rikkyo University.

Introduction: A mid-infrared imager is being prepared for mapping thermal emission of a C-class near-earth asteroid 1999JU3 in Hayabusa-2. Purpose of this instrument is to investigate surface physical properties derived from regional variation of thermal inertia and its relationship to geomorphology, and to assess selection of landing sites from measured surface temperature and physical condition which is covered with sand, pebbles, or rocks. This instrument is based on LIR (Long-wavelength InfraRed imager) onboard Akatsuki (former Planet-C), a Japanese Venus climate orbiter, but modified its optics to be a higher spatial resolution thermal infrared imager.

Hayabusa-2: Hayabusa-2 is the immediately follow-on mission after Hayabusa, the first round-trip to asteroid and successful sample-return from there. Hayabusa is the Japanese engineering explorer to demonstrate new technologies for asteroid sample return, which was launched on 9 May 2003, rendezvous asteroid 25143 Itokawa on 12 September 2005, and returned to Earth on 13 June 2010. The substantial design of Hayabusa-2 spacecraft is based on that of Hayabusa, but some repairments and redesigns must be done to achieve more exciting, optimizing science mission. Hayabusa-2 is primarily a sample-return mission, but remote sensing near-by the asteroid have strong importance to understand the nature of the asteroid and characterize its global features, complementary to the analysis of returned samples. In this mission, an active impact experiment will be planned by excavating a few to several meters diameter of the surface to investigate the physical properties and composition of upper layer of asteroid from the produced crater dimension and the difference of the thermal inertia or spectral profile inside the crater from the surrounding original surface.

Target body for Hayabusa-2 is Asteroid 1999JU3, a C-class near-earth object. For a C-class asteroid, most optimized set of instruments are changed from Hayabusa: telescopic (multi-band) and wide-angle imagers, raser ranger (LIDAR = Light detection and ranging), near-infrared spectrometer to identify absorption band relating to aqueous alteration or water ice existence as well as organic materials. Another selected regular science instrument is the mid-infrared imager.

MIR Imager: In Hayabusa, the only data for thermal emission from the asteroid has been obtained through thermal radiometry using the temperature profile of the radiator of XRS (X-ray spectrometer). In Hayabusa-2, a mid-infrared thermal emission imager will map the surface temperature profile as a high resoltuion image and its temporal variation.

The former version of thermal mapper called LIR is carried on Akatsuki, renamed from Planet-C Venus climate orbiter (See. Figure 1). This instrument was originally developed for imaging the moving clouds of Venus at the temperature range of 220-250K. However, the LIR is expected to be used for thermal inertia of the surface materials and geologic feature imaging as a thermal emission or mid-infrared imager. Now we use the helitage of Akatsuki as much as possible because of very short period for instrument development (only 21 months) in Hayabusa-2, much shorter than that of typical missions in Japan.

The original instrument uses a non-cooled bolometer array as infrared detector, NEC 320A. The instrument onboard Hayabusa-2 will use the same detector (flight-spare of LIR) and its analog electronics. Digital electronics is basically the same as the former LIR but some detailed performance should be changed. Onboard analysis such as summation of multiple images, substraction of dark images, treatment of dead pixels, and compression for data reduction will be done in the DE (Digital Electronics) prepared for all the scientific imaging instruments.

Differential temperature mapping place to place is essential for its performance to analyze surface physical condition and constituent materials. Identification and calibration of absolute temperature and its temporal variation of the asteroid surface is also important to know the thermal inertia and assess the thermal condition for the surface touchdown operation of the spacecraft to collect samples.

Characteric performace of the instrument is shown in Table 1. The total mass is less than 4 kg including the detector, hood, preamplifier circuit, amplifier and analog to digital converter, tememetry/command interface to DE, and power supply (DC/DC converter) to regulate power from unstable 50 V power supply from the spacecraft.

Table 1: Characteric Performance of Mid-Infrared Termal Emission Imager of Hayabusa-2

Mass	3.7 kg
Power	25W
Detector	non-cooled bolometer
Pixels (effective)	320 x 240
FOV	±5.3°x ±4.0°
IFOV	0.58 mrad
Temp. range	220 – 400 K
Absolute T resolution	< 3K
Diff.T resolution	< 0.5deg
Data	0.15MB/image

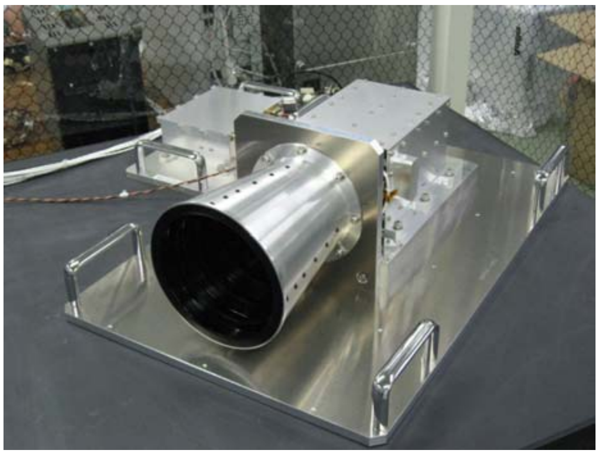

Figure 1 : Test model of the LIR onboard Akatsuki

Science Objectives in Hayabusa-2: Main scientific objectives of this mid-infrared thermal emission imager are 1) global and local areal distributeon of the surface condition such as sandy regolith, pebbles, or monolithic rocks through mid-infrared imagery, 2) tpical porosity of large boulders possibly appeared on the surface, 3) the surface material science.

Surface physical properties are to be determined through thermal emission mapping within 10 m spatial resolution from the Home Position 10 ~ 20 km sunward (earth-ward) the asteroid surface. Thermal inertia represents the surface physical condition. For sandy material, the surface thermal inertia is roughly small (<50 J $m^{-2} s^{-0.5} K^{-1}$), and the surface temperature is basically in the thermal equilibrium to the input solar radiation. For monolithic material (its thermal inertia of larger than 1000 J $m^{-2} s^{-0.5} K^{-1}$), for higher thermal inertia, surface temperature is little changed or changed only within a small range, but the delay of time for the temperature to achieve the peak is observed. For pebbles with medium value of thermal inertia (100 ~ 300 J $m^{-2} s^{-0.5} K^{-1}$), intermediate variation of temperature and delay of time is observed.

In the early stage of study for this instrument, using a filter wheel was considered for material classification from 7 to 14 micron, with each band of 0.5 or 1 micron. Mid-infrared imager will show a good performance for multiband thermal infrared imager. However, too short period of time for development prevented us from adding the multi-band functions.

Mission Operations: For Hayabusa-2, telemetry rate is limited up to 8 kbps using an X-band during the asteroid rendezvous phase, although higher downlink rate is being considered using Ka-band. The data transformation should be much reduced, especially for imaging instruments..

At Home-Position, basically the instrument works in once a week. Thermal inertia mapping will be done with thermal imaging along with asteroid rotation (7.6Hrs). When the rotation angle is quite inclined, it is necessary to take time for whole surface mapping. This is what is known only after arrival at the asteroid.

For much smaller sites to be observed such as pond like features, boulders, and inside the craters, observation of local area thermal inertia and subsurface physical parameters are requested during the descent phase operation. Imaging type of instrument has an advantage to observe relative to scanning type ones, so this instrument will be mainly used for investigating surface feature and thermal mapping. Possibly the detailed shape and physical properties of the small crater produced by active impact experiment is to be observed by this method.

Summary: Development of a mid-infrared imager for Hayabusa-2 is just started for thermal emission imaging and determining the surface thermal inertia. This instrument should help us understand the nature of a C-class asteroid 1999JU3 before its sample is returned to the Earth.

References:

Fukuhara, T. *et al.*, Solar system science , PP. 927, 2010.