THERMAL INFRARED MULTIBAND IMAGER TIRI FOR ESA HERA MISSION TO DIDYMOS BINARY ASTEOID. T. Okada[1,2], S. Tanaka[1], N. Sakatani[1], Y. Shimaki[1], T. Arai[3], H. Senshu[4], H. Demura[5], T. Sekiguchi[6], T. Kouyama[7], M. Kanamaru[2], T. Ishizaki[1], H. Saito[5], R. Konno[5], Z.-L. Li[1,2], S. Furukawa[1,2], J. Blommaert[8,9], O. Karatekin[10], and the Hera TIRI Team, [1]Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), 3-1-1 Yoshinodai, Chuo, Sagamihara 252-5210, Japan, email: okada@planeta.sci.isas.jaxa.jp, [2]University of Tokyo, Japan, [3]Maebashi Institute of Technology, Japan, [4]PERC, Chiba Institute of Technology, Japan, [5]University of Aizu, Japan, [6]Hokkaido University of Education, Asahikawa, Japan, [7]National Institute of Advanced Industrial Science and Technology (AIST), Japan, [8]VITO, Belgium, [9]Vrije Universiteit Brussel, Belgium, [10]Royal Observatory of Belgium, Brussels, Belgium.

Introduction: TIRI is the thermal infrared imager based on an uncooled micro-bolometer array with a multi-band filter wheel, and being developed for the ESA Hera mission [1] to investigate thermophysical properties and constitute materials of the surface of the S-type near-Earth asteroid 65803 Didymos and its small moon Dimorphos. A flight-model equivalent engineering model (EQM) has been manufactured for electrical, communicational, and environmental tests at qualified level. Its proto-flight model (PFM) is the same design as the EQM except for its parts assurance level, and almost ready for its develooment. Here we introduce the TIRI instrument and its characteristics to achieve the science and mission objectives as well as its status of development.

Hera Mission and Objectives: Hera is the first planetary defense mission organized by the Planetary Defence Office of ESA, and jointly consists the first international planetary defense mission called AIDA (Asteroid Impact & Deflection Assessment) with the NASA DART (Double-Asteroid Redirection Test) mission [2]. DART was launched on 24 Nov 2021 (UTC) and made a kinetic impact to Dimorphos on 26 September 2022 (UTC), and it was reported that the rotation period of Dimorphos around Didymos was reduced by 32 minutes, from 11h55m to 11h23m, and the impact flash and the dust ejection were observed from a 6U CubeSat called LICIACube as well as from many ground observatories.

Hera will be launched in 2024, arrive at Didymos binary system in early 2027, and start the observations of Didymos and Dimorphos during a half year long rendezvous phase. The remnants of the DART impact such as the artificial crater and ejecta sediments as well as orbital and rotational conditions of the asteroids will be investigated using the data obtained by Hera, to evaluate the effect of deflection by the DART kinetic impact to Dimorphos. Science of the asteroid binary is also significantly important although it is regarded as the by-product in the Hera mission.

Target Binary Asteroids: Didymos is among a potentially hazardous asteroid, with its orbital period of 2.108 years, its perihelion and aphelion of 1.0134 au x 2.2753 au, its absolute magnitude (H) of 18.07, its geometric albedo of 0.15, and its diameter of ~780 m. Its taxonomic class is more like an S-type [1], and its bulk density is estimated as ~2100 kg m^{-3}, which is a typipcal value of a sub-kilometer sized ruble pile S-type asteroid. The S-type asteroid Itokawa has a similar density of ~1900 kg m^{-3} [3]. The surface may be partly covered with the sediments from the ejecta generated by the DART impact.

Dimorphos remains unclassified for its taxonomic class even after the DART impact, and poorly known about its physical properties although now we know it is a rubble-pile body without fine regolith flat areas but covered with boulders. The orbit of Dimorphos has changed and its rotation period is reduced from 11.9 to 11.4 hours, probably rotating an eclipse orbit smaller than 1.19 km from the center of Didymos. Its diameter was originally estimated ~160 m, and it shape was imaged with the on-board camera of DART just before impact as a slightly flattened spheroidal shape, but its current size and shape is unknown.

TIRI Instrument: TIRI consists of the bolometer based sensor unit (BOL) and the science data handling electronics unit (SHU). Its total mass is 4.0 ± 0.4 kg and the power consumption is around 15 ± 1 W for nominal operations, and the peak power is ~20 W when the internal heater is used. Its envelope size is within 190 x 230 x 263 mm, including the radiator and the six legs to fasten the instrument to the top panel of the Hera spacecraft. TIRI is supplied unregulated 28 V to operate its electronics and for thermal conditioning with two channel heaters. TIRI communicates via SpaceWire with command and telemetry interface to the spacecraft data handling unit.

Sensor Unit BOL: BOL is based on the bolometer (Lynred PICO1024 Gen2) of 1024 x 768 pixels, takes images at 25 Hz, able to integrate 2^N (N=0, 1, …, 7) of images to increase signal to noise ratio. TIRI covers the wavelength of 7 to 14 µm, with the wide band filter of 8-14 µm for thermal imaging and with six narrow band filters centered at 7.8, 8.6, 9.6, 10.6, 11.6, 13.0 µm for composition mapping, with the filter wheel. TIRI is designed to have the FOV of 13.3° x 10.0° to image the whole asteroid binary system from 20 km distance, and the IFOV of 0.013°/pixel (0.23 mrad) to discriminate the surface geologic feature such as the artificial crater formed by the DART impact, with the spatial resolution of 4.6-6.9 m/pixel from 20-30 km distance during the early characterization phase, and 0.23-0.46 m from 1-2 km distance during the closest flybys. TIRI is capable of detecting the temperature of 150 to 450 K, with the absolute accuracy of 2K and the noise equivalent temperature difference (NETD) is < 0.1 K at 300K.

Electronics Unit SHU: SHU is the electronics based on FPGA (Microchip, RTAX2000S), with the functions of driving the bolometer, image readout from bolometer, image integration, summation from background images, image storage in FLASH (max 2039 images), image compression, image extraction of region of interest (ROI), packtization into CCSDS packet, as well as houskeeoing and status output. SHU also detects and executes the commands via the data handling unit of the Hera spacecraft, and detects the onboard time. SHU also control the filter wheel and internal heater.

TIRI Tests: The test of TIRI EQM has started in the manufacturer (Fig.1). During its preliminary check and performance test, TIRI EQM has already shown its proper performance for all the commands as well as continuous telemetry outputs of houskeeping, status, and image data, using the payload interface checker (PIFC) provided by ESA, which is recognized as TIRI EQM passed the communication tests with the Hera system. The NETD is below 0.1 K at 300 K after integration of 16 images. The temperature detection range is tested from the blackbody target temperature of 10 to 125 ℃, able to extrapolate the range to 150 to 450 K, because of its linearity of TIRI detection intensity with the thermal radiance (Fig.2). Its FOV was checked using the two axis rotation stage covering the whole FOV, although rim darkening and a slight distortion (a few %) was observed. TIRI EQM was opperational for a wide range of temperature from -30 to + 60 ℃ in the atmospheric chamber. TIRI EQM was also checked its electromagnetic compatibility, waiting for the final agreement by ESA. The other environmental tests such as thermal vacuum, thermal valance, vibration, shock, and other electrical tests are planned in early 2023.

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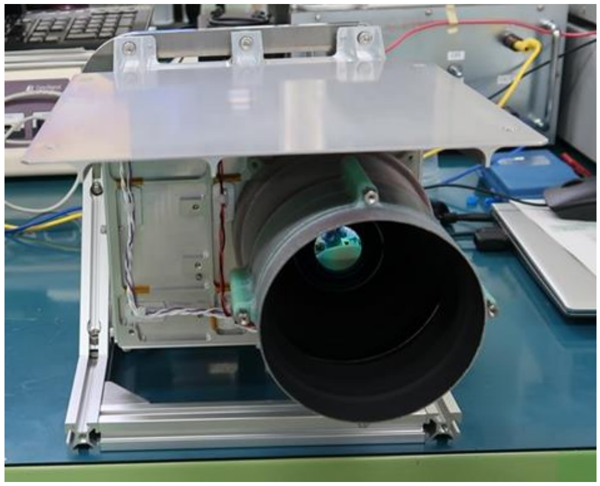

Fig.1 TIRI EQM in the clean room of the manufacturer.

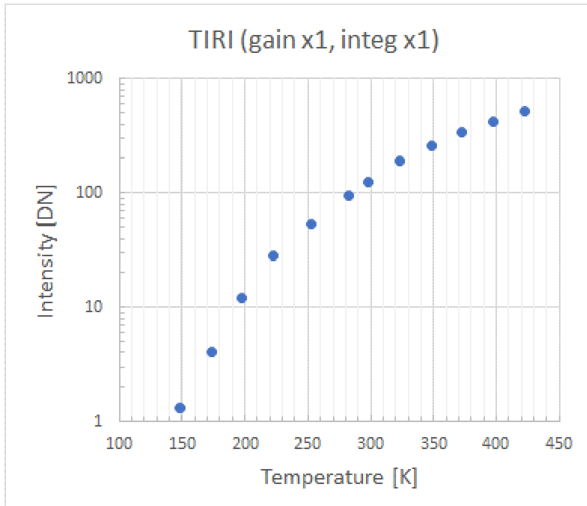

Fig.2 Preliminary test result for detectability of TIRI. The data points below 270 K are extrapolated from the higher temperature, considering the linearity of intensity (DN) to the radiance detected by TIRI.