# Thermal Infrared Multi-band Imager for the Hera Mission

*Tatsuaki Okada[1,2], Tetsuya Fukuhara[3], Satoshi Tanaka[1], Takehiko Arai[4], Naoya Sakatani[1], Yuri Shimaki[1], Hiroki Senshu[5], Hirohide Demura[6], Toru Kouyama[7], Tomohiko Sekiguchi[8], Sunao Hasegawa[1], Makoto Yoshikawa[1]

1. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2. University of Tokyo, 3. Rikkyo University, 4. Ashikaga University, 5. Chiba Institute of Technology, 6. University of Aizu, 7. National Institute of Advanced Industrial Science and Technology, 8. Hokkaido University of Education

**Introduction:** Thermal infrared multi-band imager TIRI is now under study to investigate thermophysical properties and materials of the surface of S-type binary asteroid Didymos in the ESA Hera mission.

**Hera Mission:** Hera is the ESA's asteroid mission to explore the S-type binary asteroids Didymos (780 m in diameter, 2.26 hours in rotation, 2.1 kg $m^{-3}$) and its moon (160 m in diameter, 11.9 hours in 1.2 km orbit), and a part of the first international planetary defense mission AIDA (Asteroid Impact and Deflection Assessment) with the NASA DART (Double-Asteroid Redirection Test) mission [2]. DART will be launched in 2021 and perform an impact to Didymoon in 2022. Impact phenomena like impact flash and the moon's orbit change will be observed by ground observations, but the dimension of impact crater, the possible alteration of materials, and the detailed orbit and nutation will be observed by Hera. Hera will be launched in 2024 and arrive at the binary asteroid in 2027.

**Hera Operations:** Early Phase will start at 30 to 20 km altitude, followed by observations at the altitude of 20 to 10 km. CubeSats will be deployed, followed by observations at 20 to 10 km, then at 10 to 5 km. Finally, Extended Phase will start for closer flyby or orbiting the Didymos.

**TIRI Instrument:** TIRI is a one-box instrument, consisting of the sensor unit BOL and the electronics unit SHU, with the targeted specification of the total mass < 5 kg, the power < 30 W, and the envelope area < 300 x 150 x 200 mm. Power of unregulated 28 V and 2 channel survival heaters are supplied from the Hera spacecraft. A basic design is from UNIFORM2 [3].

***BOL:*** BOL is based on an uncooled micro-bolometer array of 1024 x 768 pixels, reads at 60 Hz, covers 8 to 14 $\mu$m wavelength, and has the FOV of 10° x 7.5°. The detector is pre-calibrated before launch to convert to brightness temperatures. Detector temperature should be controlled using a Peltier during operation. BOL has a capability of multi-band thermal imaging using an 8-point filter wheel, 3 narrow bands for Christensen Features (CF) at 8-10 $\mu$m, the other 3 bands for Reststrahlen Features (RF) around 11-13 $\mu$m, another one wide band for 8 to 14 $\mu$m or no filter for thermal imaging, and the rest for blank as a shutter. BOL possibly has a mechanical shutter outside of the 100 mm-diameter aperture, for on-board temperature calibration and direct insolation avoidance.

***SHU:*** SHU has the functions of data readout from BOL, an on-board data processing, a HK collection, a packet production, a command and telemetry control via Spacewire, a power supply control, a filter wheel control, and a shutter control. SHU captures the raw thermal images of 1024 x 768 pixels at 14 bit depth at 30 or 60 Hz. Image integration and bit-shifts are performed to produce high-S/N 15-bit images. Dark frame subtraction is performed with shutter-close or deep sky images before lossless image compression and CCS-DS packetization. The packets are stored into telemetry queue buffers, to be sent to the spacecraft OBC via Spacewire. The concept is inherited from TIR [4].

 

**Contribution to Hera by Japan:** In addition to remote sensing of surface physical state of the binary asteroid by TIRI, just lilke the TIR on Hayabusa2 [5], Japanese contribution to Hera is strongly desired for its advanced experiences in Hayabusa2 mission: impact experiment and simulations, shape modeling, thermal mapping, operations at asteroid approach and proximity, and ground observations.

**Acknowledgments:** This work is partly supported by ISAS/JAXA Research Fund for International Collaborative Missions in FY2019.

**References:** [1] Carnelli I. et al. (2019) *ISTS2019*, Fukui, 16-21 June 2019, 2019-o3-04. [2] Cheng A.F. et al. (2018) *PSS* 157, 104-115. [3] Fukuhara T. et al. (2017) *IEEE Trans. Geosci. Rem. Sens.* 55, 4314-4324. [4] Okada T. et al. (2017) *SSR.* 208, 255-286. [5] Okada T. et al. (2020) *Nature*, in print.

Keywords: Hera, Planetary Defense, Thermal Imaging

 