Performance evaluation of Nano-JASMINE telescope flight model

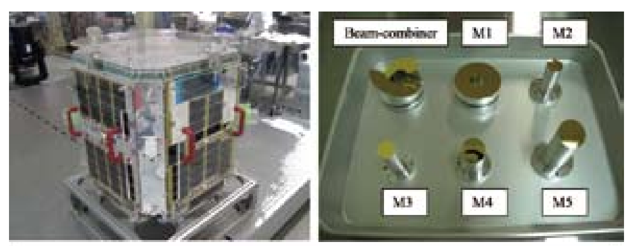
NIWA, Yoshito (NAOJ)
HATSUTORI, Yoichi (IBM Japan, Ltd.)
KOBAYASHI, Yukiyasu, GOUDA, Naoteru, YANO, Taihei (NAOJ)
YAMADA, Yoshiyuki (Kyoto university)

Nano-JASMINE is a very small, 35-kg mass, satellite for space astrometry[1,2], which will be launched by Cyclone-4 rocket from Brazil in 2011. The satellite is developed by National Astronomical Observatory of Japan, Kyoto University and University of Tokyo. Nano-JASMINE mounts a 5-cm effective diameter telescope and a time-delay integration (TDI) controlled fully depleted charge coupled device (FDCCD) image sensor which is sensitive to wavelength of zw-band ($600 < \lambda < 1000$ nm). Nano-JASMINE will perform firsttime demonstrations and experimentations for Japan astrometry mission in space. These trials are targeting for Japan Astrometry Satellite Mission for Infrared Exploration (JASMINE)[3]. By Nano-JASMINE mission, we are also going to measure positions of ten or twenty thousands of stars of zw < 7.5 mag for all-sky with an accuracy of about 3 milli-arcsecond.

Astrometry is a field of observational astrophysics that measures positions and proper motions of stars on the celestial sphere, and determines the distances to stars from the earth using trigonometric parallaxes due to earth orbit around the sun. Space telescopes for astrometry have much more advantage than ground-based telescopes; because of the effect of atmospheric motions, observed star images are blurry in the case of ground-based observations. Therefore, HIPPARCOS was launched by ESA in 1989, and observed about hundreds of thousands of star positions around the all-sky with one milli-arcsecond angular accuracy. In 2011, almost 22 years have passed since the end of the HIPPARCOS mission. Then, the errors in proper motions have accumulated over the years; the individual motions of stars and their uncertainties are large enough to degrade the HIPPARCOS data during these two decades of blank. Therefore, the Nano- JASMINE mission is beneficial.

Currently, satellite functional tests, which include electrical integration tests, vibration tests, thermal vacuum tests, and radiation tests, have almost finished, and long duration operational tests are in the process in preparation for the launch in August 2011. In this paper, we report a result of performance evaluation of mission system: a measurement of wave front error for the telescope.

If there are mirror surface errors for the telescope, such errors cause optical aberrations. Accordingly, shapes of point spread functions (PSF) are distorted, and the centroids of stellar images will be changed from true positions. Total budget for root mean square (RMS) wave front error is $\lambda/14$ at $\lambda = 800$ nm. The wave front error was measured for each mirror surface by use of a Zygo interferometer. The results are shown in Fig. 1. The total RMS wave front errors are both $\lambda/17$ at $\lambda = 800$ nm for upper and lower optical system. We also directly measured total wave front error for the fabricated telescope, which was placed in vacuum chamber and cool downed to 223 K, which is equal to the operating temperature on the orbit. As a result, the total RMS wave front errors are $\lambda/19$ and $\lambda/21$ for upper and lower optical system, respectively. This result indicates that the error level fulfills the requirement so that the telescope is given assurance for diffraction-limited performance on the orbit.



Mirror	RMS Wave front error (nm)	
	Upper	Lower
Beam combiner	16.6	14.2
1st	33.2	
2nd	20.6	
3rd	12.7	
4th	11.1	
5th	13.5	
Total	**47.4**	**46.9**

Figure 1: Top left: the flight model of Nano-JASMINE. Top right: the flight model of the telescope mirrors; M1 and M2 are hyperboloid mirrors as a primary mirror and a secondary mirror, respectively. M3 ~ M4 are flat mirrors. Bottom: wave front error of each mirror surface.

References

[1] Kobayashi, Y., et al.: 2006, *SPIE*, **6265**, 626544 1-10.
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[3] Gouda, N.: 2011, *EAS Publications Series*, **45**, 393-396.