Development of PLANETS telescope: An attempt to reduce polishing volume in final polishing process by using an active mirror support

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PLANETS (Polarized Light from Atmospheres of Nearby Extra-Terrestrial Systems) telescope is a 1.85 m off-axis telescope. It is developed with technical support from Nagoya University and Kyoto University, and in international collaboration between Tohoku University, Hawaii, Germany, and Brazil. It is going to be temporally installed in Japan late in 2021, and will be finally installed at the Haleakala observatory, one of the world’s best astronomical observation sites. PLANETS telescope is the only medium aperture telescope in Japan located at Hawaii longitude, and can be a base for collaborative observations with small and medium aperture telescopes in Japan. The main targets of the PLANETS telescope are faint luminous phenomena around bright bodies, such as material eruptions from Io, Europa, Enceladus, and other solar system objects, and the rarefied atmospheres around Mars and Venus. To achieve these observations, it is necessary to suppress the diffraction and scattering of light from the bright bodies effectively and to increase the contrast with the faint emission spreading to the surroundings. PLANETS telescope is one of the biggest off-axis telescopes except for solar telescopes. It uses a Gregorian type with a concave elliptic secondary mirror, and there is no obstacle on the light path such as secondary mirror and its support structure, so there is no diffraction from them. Combining the off-axis design with a coronagraph and an adaptive optics enables high-contrast observations. In addition, long-term continuous observations are necessary to understand such atmospheric and plasma phenomena. PLANETS telescope can make a significant contribution to understand planetary atmospheric phenomena because it will be used for dedicated observation of own instrument and can provide a large amount of observation time. In this presentation, we report an attempt to reduce the polishing volume by using an active support mechanism in the final polishing of the primary mirror, which will start in May 2021, and the results of a test to verify the operation of the support mechanism.

The primary mirror is a Clearceram-Z HS with a diameter of 1.85 m and an edge thickness of 100 mm. As of February 2021, the primary mirror has been figured to surface error of 1.50 μm RMS, and the final polishing scheduled for May 2021 aims to achieve the surface error < 20 nm RMS for 30-cm spatial scale. Large volume of mirror material to be removed by polishing (polishing volume) leads to an increase in the time and cost required, so smaller polishing volume is desirable. We will reduce the polishing volume by using both of the following two methods. In the first method, a radius of curvature of the off-axis paraboloid, an off-axis distance, tip-tilt of the mirror surface and a rotation angle are adjusted so that the polishing volume is minimized for the mirror surface error. Changes of these parameters deform the surface figure linearly and independently when the parameter changes are small amounts. By tuning these parameters, the best-fit parameters are determined so that the polishing volume is minimized. This minimization basically reduces polishing volume by less than half for the surface figure error expressed up to the third order of Zernike polynomial with 2μm RMS amplitude. In the second method, the active support mechanism of the primary mirror is also applied to correct the surface figure error to reduce the polishing volume. PLANETS telescope uses a 36-point whiffletree for the axial support of the primary mirror. The whiffletree is combined with 33 warping harnesses consisting of leaf springs and linear motors to control the support force at each support point. This axial support is also used in the final polishing to reduce the polishing volume by decreasing the surface figure error on large spatial scales. We used finite element analysis to validate the second method. Combination of these two methods successfully deforms the mirror surface in shapes expressed as Zernike polynomials up to the third order and less than about 20% error. We also simulated the minimization of the polishing volume for the current figure error of the primary mirror in advance of the final polishing. As a result, it was expected that the mirror surface error could be reduced from 1.5 μm RMS to 0.28 μm RMS, and the amount of polishing could be reduced by 80.5 %.

Prior to the final polishing, we are making tests to confirm the control repeatability and stability of the active support mechanism using the primary mirror and autocollimator. We will report the latest results in this presentation.

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