THE OVERVIEW OF THE PLANETARY ATMOSPHERIC SPECTRAL TELESCOPE (PAST) IN THE SCIENTIFIC EXPERIMENTAL SYSTEM IN NEAR-SPACE (SENSE)

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ABSTRACT:

To investigate mass transport and energy dissipation in space environments for solar system planet, a balloon-borne planetary atmospheric spectral telescope (PAST) is designed with 0.8-m aperture in spectral range from 280 nm to 680 nm will be floated at 35-40 km altitude to observe and investigate the global space environment of Mercury, Venus, Mars, and Jupiter. The telescope is designed by Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences (CIOMP, CAS), and supported by the Strategic Priority Research Program of Chinese Academy of Sciences, that is the Scientific Experimental system in Near-SpacE (SENSE). The telescope is mainly supported by a Ritchey-Chrétien optical system which can achieve 0.5" angular resolution observation, and the optical system has the function of focusing and stabilizing. The telescope is combined with a two-dimension rotate platform to achieve planetary atmospheric imaging in long exposure time. This paper mainly introduces the PAST scheme briefly.

1. INTRODUCTION

Planetary Atmospheric Plasma Coupling and Comparative Research is a project of the Scientific Experimental system in Near-SpacE (SENSE), and it proposes a global atmospheric remote sensing observation of the atmospheric environment of the near-Earth planet based on the aerostat platform. The designed telescope will be floated on earth atmospheric stratosphere. to observer the thin atmosphere of solar system planets including Venus, Mars, and Jupiter and so on. The observation band covers the ultraviolet to visible light and acquires the main components or characteristic components of the planet. The purpose of the project is to obtain information on the global atmospheric multispectral distribution of the main components or characteristic components of the atmosphere and its evolution information for comparative planetary studies. The research of the subject is expected to make important achievements in revealing the diversity of planetary atmospheric environment evolution and solar energy regulation of the planetary atmosphere.

According to the needs of scientific goals, the PAST which is with a large-aperture, a working spectrum band from ultraviolet to visible was established. PAST will be mounted on an aerostat platform to achieve multispectral imaging of terrestrial planet atmospheres to study the diversity of planetary atmospheric environmental evolution.

2. PAST SCHEME

2.1 Main Technical Index

According to the task，the PAST main technical index is shown in Table 1.

No.	technical index	value	
1	Aperture (mm)	800 mm	
2	Field of view (FOV)	2ω=15′	
3	Resolution (″)	0.5	
4	spectral range (nm)	280-680	280-680 for planetary atmospheric observation 400-680 for Planetary sensor
6	Stray light coefficient	Less than 5% (beyond 20°about optical axis)	

Table 1 The main technical index of PAST

2.2 Optical System Scheme

The PAST adopts a catadioptric optical system whose foundation is a Ritchey Chrétien system which has the ability to achieve a well image quality for 15′ FOV with the correcting lenses. In the back focal length, the focusing mirror and stabilizing mirror are set. A beam splitter prism divides the ray path into two parts, one part is for planetary atmospheric spectral imaging (scientific imaging), and the other part is for a planet sensor.

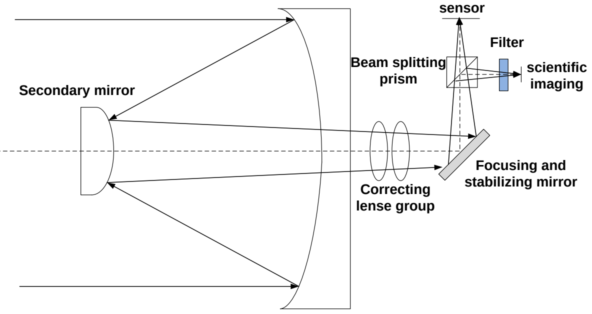


Figure 1 Optical System Scheme

The focal length of the system is 5600mm, the relative aperture is 1:7, the field of view is 2ω=15′, and the working spectrum is 280nm-680nm. The relative aperture of the primary mirror is 1:1.75, the secondary mirror magnification is -4, the primary mirror (PM) and secondary mirror (SM) distance is 957mm, and the total length of the system is about 1500mm.

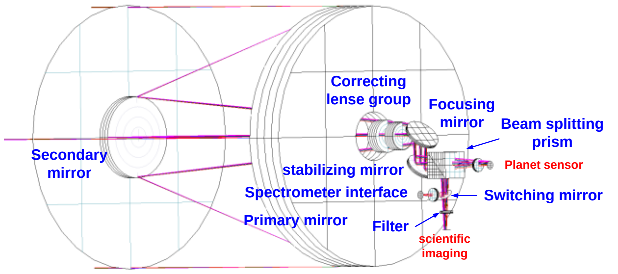


Figure 2 Optical system design result

The optical system can be divided into a front optical portion and a rear optical portion. The front optical portion mainly includes a concave PM and a convex SM, and the remaining optical components are in the rear optical portion, as shown in Figure 2. After the light passes through the PM and SM, the light enters the rear optical portion. In the rear optical path portion, the light first passes through the correcting lens group, and then passes through the two plane mirrors, the former is used for focusing, and the latter is used for stabilization.

The light passes through the cube beam splitting prism and divides the light path into two parts by the functional film layer. The light reflected by the beam splitting prism is used for planetary atmospheric spectral scientific observation and spectrometer imaging (a folder mirror will fold the light into a spectrometer when the planetary atmospheric spectral scientific observation suspends work), and the light transmitted by the beam splitting prism is used to planet sensor.

In the scientific observation and spectrometer imaging optical path, the spectrometer switching mirror (planar mirror) is used to time-separate the scientific observation focal plane and the spectrometer focal plane, shown in Figure 2. A filter wheel is placed in front of the scientific observation focus to achieve selective imaging of different scientific observations. In order to ensure the optical path of each light path is consistent, an optical path compensation sheet is set in front of other focal points.

Figure 3 The filter wheel

The point spread function is an important criterion for evaluating star point images. After the optical system is designed, the point spread function is evaluated. In the analysis, the six field of view points of the system are selected, and the optical system point spread function is symmetric in shape and good in energy concentration, shown in Figure 4. The system RMS wavefront error average value is 0.0218λ (λ=480nm), shown in Figure 5.

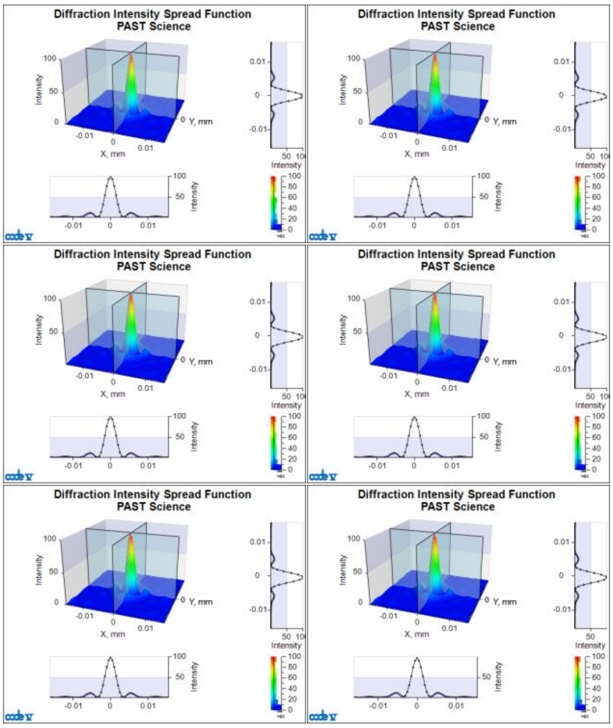


Figure 4 The system point spread function

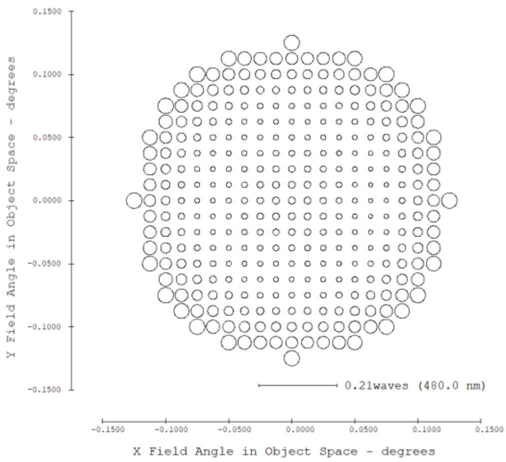


Figure 5 RMS wavefront error

Due to the field of view value is small, the PAST optical system has a good performance in distortion value, the largest value is less than 0.01%, the distortion value is shown in Table 2, and the distortion curve is shown in Figure 6.

Relative field of view	Distortion (%)
0	0
0.1	0.00008
0.2	0.00033
0.3	0.00074

0.4	0.00131
0.5	0.00205
0.6	0.00295
0.7	0.00401
0.8	0.00524
0.9	0.00663
1	0.00819

Table 2 Distortion

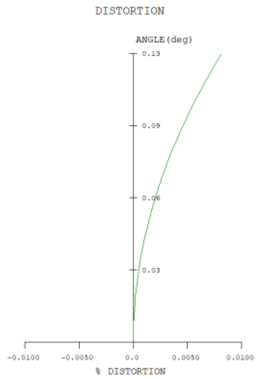


Figure 6 Distortion curve

The optomechanical structure of the telescope includes the stray light suppression structure, includes the hoods, the light blocking rings and diaphragm, etc, shown in Figure 7. The stray light suppression black paint is sprayed inside the optomechanical structure, the absorption rate among the visible spectrum band is large than 95%.

In Tracepro software, rays are traced in all directions beyond 20°, analyzing the stray path outside the field of view, the stray light coefficient is 3.1%, the point source transmission (PST) ratio curve is shown in Figure 8.

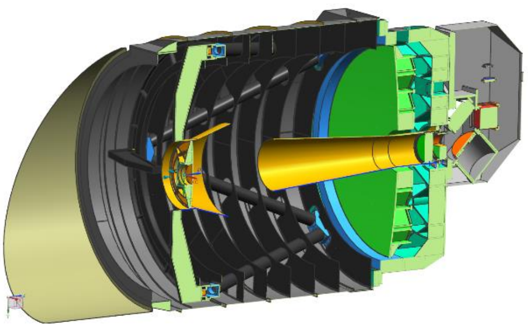


Figure 7 Stray light suppression structure

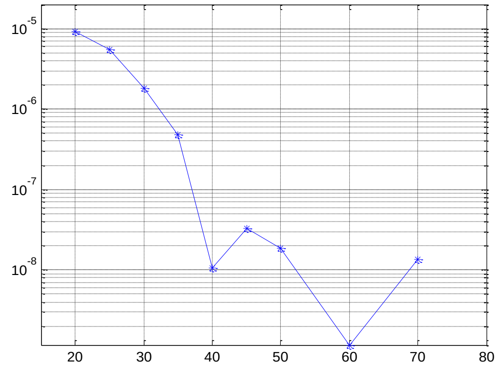
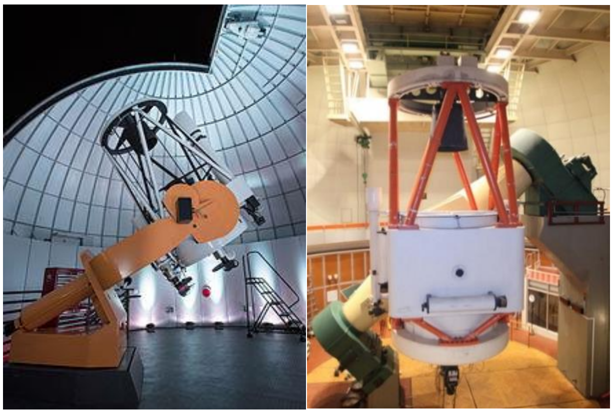


Figure 8 PST curve

2.3 Opto-Mechanics Scheme

In the design of the optomechanical structure, we refer to the structure of the Ritchey-Chrétien telescope in Embry-Riddle observatory, and the 2.16m telescope at the Xinglong Observatory in Hebei, China, shown in Figure 9. These telescopes are close to PAST in terms of main mirror size and system specifications, and these telescopes are all truss-type structures.



(a) (b)

Figure 9 (a) the Ritchey-Chrétien telescope in Embry-Riddle observatory© wikipedia Image Copyright 2019; (b) the 2.16m telescope at the Xinglong Observatory in Hebei, China ©National Astronomical Observatories, Chinese Academy of Sciences Image Copyright 2019

PAST structure is mainly composed of the following parts: PM room, PM structural support, PM support ring, truss rod, SM structural component, SM hood, SM support ring, and spider support and so on, shown in Figure 10. To ensure mechanical properties and reduce system quality, PAST structure is mainly designed with carbon fiber material and titanium alloy material.

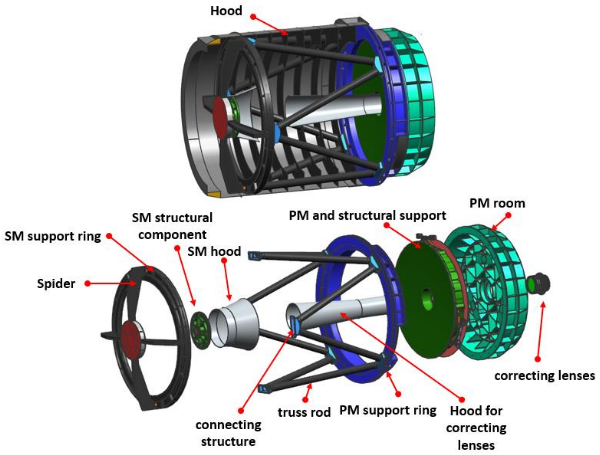
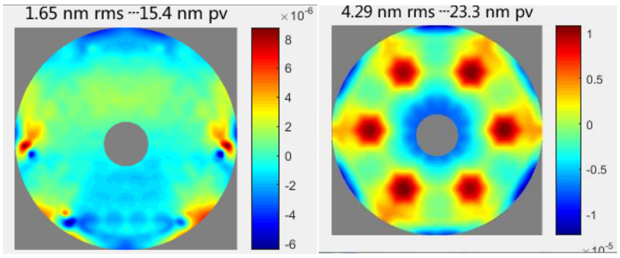


Figure 10 Machinery exploded figure of telescope

The large-aperture mirror surface error performance is the key to static design. Finite element model has been analyzed for the mirror surface shape error in the optical axis horizontal state and the optical axis vertical state, and it shows that the mirror shape error achieves a perfornance value shown in Figure 11.



(a) Horizontal optical axis (b)Vertical optical axis

Figure 11 Finite element analysis for mirror shapr error

2.4 Two-Dimension Rotate Platform Scheme

Two-Dimension Rotate Platform is chosen from the mature product of Changchun Institute of Optics, Fine Mechanics and Physics, shown in Figure 12. The total weight of the two-dimensional rotating platform and telescope is 700 kg. The telescope is placed on a balloon platform which almost 1000kg.

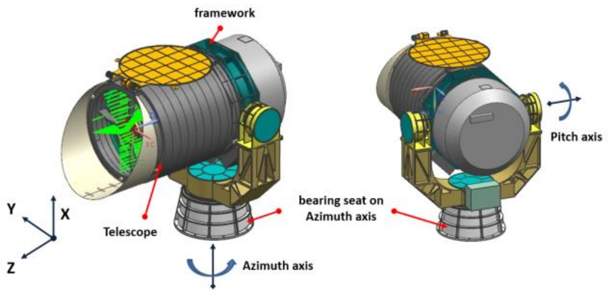
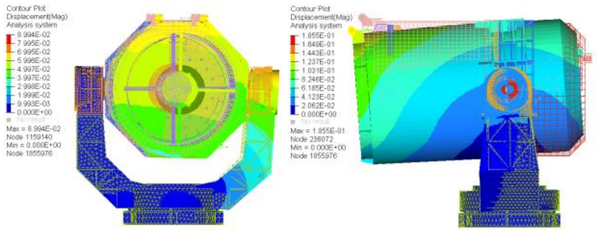


Figure 12 Two-Dimension Rotate Platform Scheme

The structural modal frequencies of the optical axis 0° and the optical axis 65° are calculated separately. The first two frequencies of the whole machine are shown in Table 3. The fundamental frequency of the whole machine is 22.7 Hz in both the optical axis 0 ° and the optical axis 65°. The first two modes of the whole machine in different states are shown in Table 3.

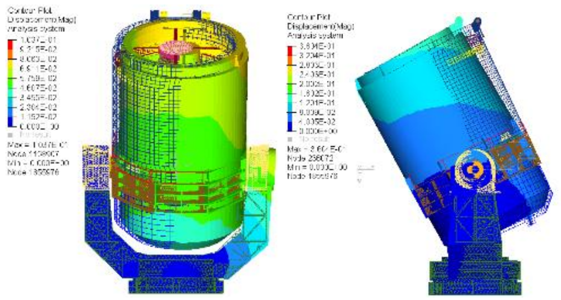
	Horizontal optical axis	Vertical optical axis
First order frequency/Hz	22.74	22.74
Second order frequency/Hz	40.53	46.23

Table 3 Vibration frequency of the whole machine under different conditions



(a) First order mode (b) Second order mode

Figure 13 Modal analysis in optical axis 0°



(a) First order mode (b) Second order mode

Figure 14 Modal analysis in optical axis 65°

3. CONCLUSION

The PAST is mainly composed of a two-mirror catadioptric telescope and a two-dimension rotate platform. It will be floated in 2020 at 35-40 km altitude earth atmospheric stratosphere to observe and investigate the global space environment of Mercury, Venus, Mars, and Jupiter and so on. Now, the PAST project design has been completed and the manufacture has been started from January 2019. We will release the PAST program progress timely in future.

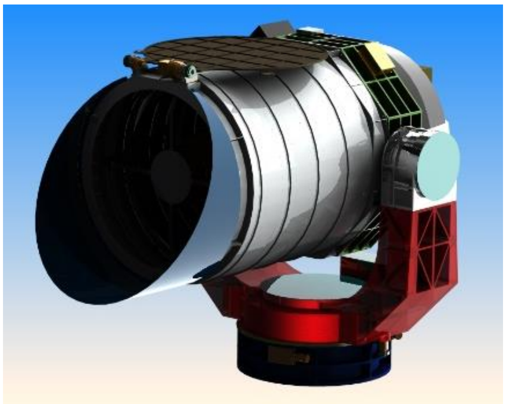


Figure 15 Outside view of PAST

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