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An in-orbit Thermal Design of Optical Window in Space Solar Telescope† ⋆

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Abstract A complex space environment will influence a space solar telescope during its in-orbit operation, and the temperature change of the optical window will affect directly the imaging quality of the optical system behind it. The purpose of the thermal design is to ensure that all the parts of the optical window keep their temperature in a normal range, more importantly, to ensure that the window can rapidly return to its working state as soon as the Earth shadowing is ended, and to complete the operation in a whole period. In order to obtain the temperature distribution and the temperature variation of the window under the space thermal load in the whole period, we have made the steady-state simulation analysis and transient-state simulation analysis of the window with and without heating during the Earth-shadow time. A good thermal control result is obtained by comparing the two kinds of transient state simulation results of the temperature distribution, and by accordingly taking the appropriate thermal control measures on the window.

Key words telescopes, optical window, eclipses, techniques: thermal design, methods: contrastive analysis

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1. INTRODUCTION

Taking the advantage of the 25th solar activity maximum, a solar maximum year exploration satellite, the Advanced Space-based Solar Observatory (ASO-S), will be developed and launched independently in China to realize the zero breakthrough of Chinese solar maximum year satellite exploration.

The advanced space-based solar observatory (ASO-S) is composed of 3 payloads: the full-disk vector magnetograph (FMG), hard X-ray imaging instrument (HXI), and Lyman-α solar telescope (LST). The magnetograph is composed mainly by three major systems: the imaging optical system, polarimetric optical system, and CCD image acquisition and processing system, in which the incident optical window is one of important components of the imaging optical system of the magnetograph, and an in-orbit thermal design of the optical window is one of the key-important techniques.

As the optical window is directly exposed to the space, its exterior is a complex space environment, during the in-orbit operation, it will be affected alternatively by the solar radiation, terrestrial infrared radiation, Earth albedo, space environment pollution, etc. Hence, the incident window plays the roles to reduce the effect of external space environment on the behind systems, to transmit the visible light, and to prevent the infrared radiation and pollution, etc. The heat exchange of the incident window with the ambient environment leads to an inhomogeneous temperature variation of the window, including the variation of the whole-body temperature, the radial temperature difference, circumferential temperature difference, and axial temperature difference. These temperature gradients will cause the deformation of the incident window glass, affect the light transmission, and finally affect the CCD image quality[1].

According to the analogue simulation, if we do not make heating on the window during the Earth-shadow time, it will need a very long time to recover after exiting from the Earth shadow, even longer than one whole period, this is obviously unreasonable. In order to have the window rapidly return to its working state as soon as it exits from the Earth shadow, by combining a passive thermal control with an active thermal control during the Earth-shadow time, and by comparing the two cases with heating and without heating, we have found an appropriate heating scheme during the Earth-shadow time, and obtained a fairly good thermal control effect[2].

2. MODELING OF OPTICAL WINDOW THERMAL DESIGN

2.1 Establishment of the 3D Model

In this paper the incident window is mainly required to transmit the visible light, so we can combine a few optical lenses with filtering functions to make them to be transparent only for the visible light.

After the selection of combination, the optical window is combined by three pieces of