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The Solar Optical Telescope of *Solar-B* (*Hinode*): The Optical Telescope Assembly

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Abstract The Solar Optical Telescope (SOT) aboard the *Solar-B* satellite (*Hinode*) is designed to perform high-precision photometric and polarimetric observations of the Sun in visible light spectra (388 – 668 nm) with a spatial resolution of 0.2 – 0.3 arcsec. The SOT consists of two optically separable components: the Optical Telescope Assembly (OTA), consisting of a 50-cm aperture Gregorian with a collimating lens unit and an active tip-tilt mirror, and an accompanying Focal Plane Package (FPP), housing two filtergraphs and a spectro-polarimeter. The optomechanical and optothermal performance of the OTA is crucial to attain unprecedented high-quality solar observations. We describe in detail the instrument design and expected stable diffraction-limited on-orbit performance of the OTA, the largest state-of-the-art solar telescope yet flown in space.

Keywords Sun: instrumentation · Sun: space telescope · Sun: visible light

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1. Introduction

The aim of the Solar Optical Telescope (SOT) aboard the *Solar-B* satellite (postlaunch named *Hinode*) is to provide high-precision photometric and polarimetric data to investigate magnetic origins and mechanisms of active phenomena on the Sun. Additionally, the SOT is designed to explore the physical coupling between the photosphere and the upper layers to understand the mechanism of dynamics and heating with the help of the coordinated observations from the X-Ray Telescope (Golub *et al.*, 2007; Kano *et al.*, 2008) and EUV Imaging Spectrometer (Culhane *et al.*, 2007) flown on *Hinode* (Kosugi *et al.*, 2007).

Owing to the Sun-synchronous polar orbit of *Hinode*, the SOT is expected to be able to continuously observe solar atmospheric structures, especially solar magnetic structures, with a diffraction-limited resolution and a polarization accuracy better than 10^{-3}. It is difficult for ground-based solar instruments to stably achieve these levels of performance, because the magnetic fields are concentrated in subarcsec structures that are much smaller than the atmospheric seeing-limited resolution. Magnetic components transverse to the line of sight, which give a measure of excess magnetic energy, are particularly difficult to observe and cannot be measured with any degree of accuracy if the magnetized structure is not spatially resolved. It should be stressed that observations from space have advantages not only in their capability of providing continuous coverage and high spatial resolution but also in offering wide field of view coverage and more stable intensity levels than those of ground-based observations.

The SOT was designed to meet the following basic specifications: It should observe the field of view fully, covering a moderate-sized active region of $\approx 3 \times 5$ arcmin wide, with a spatial resolution corresponding to small-scale magnetic elements of 0.2 – 0.3 arcsec and with negligibly small and/or well-calibrated instrumental polarization. The SOT comprises very sophisticated instruments and consists of two optically separable components: the Optical Telescope Assembly (OTA) and the Focal Plane Package (FPP). This paper will focus on the OTA instrument design and its diffraction-limited performance expected on orbit. A series of accompanying papers will describe other key components in detail: Tsuneta *et al.* (2008) for the overview of the SOT, Tarbell *et al.* (2008) for the FPP, Shimizu *et al.* (2004, 2008) for the image stabilization system of the SOT, and Ichimoto *et al.* (2004, 2008) for the instrumental polarization calibration of SOT.

2. OTA Instrumentation

The SOT was designed to achieve the diffraction limit as a whole system. Following a conventional definition of the diffraction limit (Maréchal criterion; see, *e.g.*, Schroeder (2000) and Wilson (1996)), we defined the goal of the SOT having a Strehl ratio larger than 0.8 at 500 nm at the center of the field view, assuming evenly budgeted Strehl ratios of 0.9 for both the OTA and the FPP. The Strehl ratio is the peak intensity of a point source formed by a telescope normalized with the peak formed by a perfect telescope of no wavefront aberration. The Strehl ratio (SR) can be expressed with a root-mean-square (rms) wavefront error (WFE) by the relation

$$\mathrm{SR} = \exp\left[-(2\pi\,\mathrm{WFE}/\lambda)^2\right],$$

and then the budget of the OTA is 25.8 nm rms WFE, whereas the SOT has 36.5 nm rms. To achieve this goal, the budget was subdivided for image-forming components and controlled during their fabrications and tests. The budget was also allocated for wavefront errors of