Prototype of a sodium laser guide star system for the Subaru telescope

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Abstract

An adaptive optics (AO) system for Subaru 8.2 m telescope is under construction. The AO system is attached to the Cassegrain focus for the near infrared instruments. Natural guide stars at visual wavelength are firstly used for the AO system. Furthermore, we are considering to incorporate a laser guide star system with the existing AO system to extend the sky area, where sufficient compensation performance can be obtained, i.e. sky coverage. We estimated that the output power of 4 W continuous-wave (CW) laser at the wavelength of sodium D_2 line is required for our AO system to assure the equivalent performance of wavefront compensation using natural guide stars.

A prototype LGS system for Subaru AO system, which have been started to develop, is introduced. A CW dye laser pumped by an Ar-ion laser is firstly used for the sodium laser source. We are planning to modify a commercially available dye laser system to increase the output power to 2 W. The beam quality, the stability of both the laser power and the oscillating wavelength and the image size of a laser guide star will be evaluated by the 1.5 m telescope facility at Communications Research Laboratory (CRL).

1. Introduction

An AO system for Subaru 8.2 m telescope is under construction for the Cassegrain near infrared instruments[(1)]. We firstly planned to use natural guide stars as a reference source to measure the distorted wavefront. The Subaru AO system is composed of a curvature wavefront sensor with 36 subapertures and a bimorph deformable mirror with 36 electrodes, which provides a low-order wavefront compensation. Both components divide the 8.2 m telescope aperture into 36 parts in the same manner. We expect that the correspondence of the geometry between the subapertures of the wavefront sensor and the electrodes of the deformable mirror will ensure an optimum and robust wavefront compensation. The wavefront is measured at a visual wavelength, while we observe astronomical objects in a near infrared wavelength. We are expecting that the AO system provides the Strehl ratio greater than 0.6 at K band for the median seeing at Mauna Kea, 0.45 arcsec at V band, by using a natural guide star brighter than 15th magnitude at R band[2]. The AO system will be installed on the Subaru telescope in the middle of 1999 to confirm the estimated performance. We also carry out first scientific observing runs to obtain corrected images in J, H and K band.

However, AO systems with natural guide stars cannot cover the sufficient sky area because of the need for a bright guide star close to an observing object. We estimated by using the standard model of the stellar distribution function[3] that the probability that the Subaru AO system can achieve the Strehl ratio of 0.4 at K band by natural guide stars is about 8 % at the galactic latitude of 90 degrees. The probability increases to 40 % at the galactic plane. Furthermore, natural guide stars at visual wavelength cannot be found in the dark cloud regions because of a fairly large optical extinction. A laser guide star system will overcome the small fraction of sky coverage[4]. We estimated that a laser guide star system combined with the existing AO system will extend the sky coverage to nearly 100 % at K band.

In this paper, the outline of currently proposed laser guide system for Subaru telescope and its prototype are reported.

2. Laser guide star system for Subaru telescope

We are planning to upgrade the existing Subaru AO system for incorporating a laser guide star system. The AO system for a laser guide star, as well as for natural guide stars, is optimized to achieve the best compensation performance at K band. An effect of focal anisoplanatism, due to the difference of the light path between infinite astronomical objects and a laser guide star located at a finite distance, is negligibly small for our low-order AO system at K band.

The laser guide star system comprises of a laser, transmitting optics, a laser diagnostic system, a safety system and an operational system. The design of the laser and transmitting optics defines image size and brightness of a laser guide star, which is an essential characteristic to estimate the performance of AO system. We estimated that the required brightness of a laser guide star would be 14th to 15th magnitude at R band, if the laser guide star was considered as a point source. The brighter laser guide star should be required to keep the same performance as the AO system with natural guide stars, because of the extension in size of the laser guide star. Usually the nearly diffraction-limit laser beam is transmitted from the ground and focused on the sodium layer at the altitude of around 90 km. Though the image size of the laser guide star on the sodium layer is limited by the atmospheric turbulence. Thus, the minimum image size that we can obtain is equivalent to the image size which approximately defined by Fried's coherence length. The expected image size of the laser guide star observed from the ground is extended as a factor of $\sqrt{2}$, or 2 in worst case, compared with the seeing size. When a laser beam is transmitted from the side of the telescope, the laser guide star is elongated due to the thickness of the sodium layer. The elongation of the laser guide star is estimated to be 1.5 arcsec in the case of Subaru telescope. If the laser beam is transmitted from the size of the Subaru telescope under the condition of median seeing at Mauna Kea, 0.45 arcsec at V band, image size that we obtain is about 1

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