UnISIS: Laser Guide Star and Natural Guide Star Adaptive Optics System

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ABSTRACT. UnISIS (University of Illinois Seeing Improvement System) is a versatile adaptive optics system mounted on a large optics bench at the coude focus of the Mount Wilson 2.5-m telescope. It was designed to have both laser guide star (LGS) and natural guide star (NGS) adaptive optics capabilities. The LGS side of the system relies on a pulsed UV laser with raw power of 30 W capable of creating an artificial laser star via Rayleigh scattering 18 km above the telescope. The LGS system can work at temporal response rates as high as 333 Hz—limited by the UV laser pulse rate—and the NGS system can work at rates up to 1.4 kHz. Each side of the system has its own high-speed wavefront sensor that runs separately, but in the LGS mode the NGS wavefront sensor is converted into a natural star tip-tilt sensor. The deformable mirror is conjugate to the telescope’s primary mirror and has one of the most densely packed sets of actuators of any adaptive optics system currently in operation. This paper provides details of the UnISIS design and describes key updates we have made to the system. We show NGS AO-corrected images from the sky from the 900 nm z-band through the 2.12 μm Ks band. The highest NGS Strehl achieved to date is 0.67 at Ks band.

Online material: color figure

1. INTRODUCTION

Many adaptive optics (AO) systems have been designed and built to produce diffraction-limited images at the focal plane of ground-based telescopes. AO systems were first conceived more than 50 years ago by Babcock (1953), and their early development (see Hardy 1998) was slowed by the lack of adequate technology like detectors, deformable mirrors, and fast computers. With AO components now readily available, it is not surprising that virtually all large astronomical telescopes have AO systems and that their number and diversity continues to grow at a rapid pace. Successful AO systems are now operating at the Keck Observatory (Wizinowich et al. 2006), the MMT Observatory (Milton et al. 2008), the VLT (Strobele et al. 2006), Palomar Observatory (Roberts 2008), the Gemini Observatories (for ALTAIR see Boccas et al. 2006; for the MCAO development see Rigaut et al. 2000; and for NICI see Toomey & Ftaclas 2003 and Chun et al. 2008), the Subaru Observatory (Takami et al. 2004), the Advanced Electro-Optical System (AEOS) telescope (Roberts & Neyman 2002), to name a few.

Natural guide star (NGS) AO systems were the first to be developed, and then, in the 1980s, experiments were started on laser guide star projection (Foy & Labeyrie 1985; Thompson & Gardner 1987; Happer et al. 1994). Laser guide star (LGS) AO systems rely on a laser beacon to illuminate a spot in the Earth’s atmosphere. Backscattered light can be produced at altitudes between 10 and 30 km by Rayleigh scattering or at altitudes of 90–95 km by resonant backscattering from atmospheric sodium atoms. LGS AO systems are among the most complex of astronomical instruments because of the need to operate these systems in a closed loop at high temporal bandwidths, the need to operate end to end at or close to the telescope’s diffraction limit, and the need to incorporate high-power laser transmission in the system design. As the astronomy community carries AO system design into the realm of extremely large telescopes, it is important to document the experience gained from more modest AO systems, especially those that achieve Strehl ratios >50%. UnISIS was initially conceived and designed as a Rayleigh LGS AO system in the era when the U.S. Air Force was declassifying their pioneering work on laser-guided AO (Fugate et al. 1994). This happened after Foy & Labeyrie (1985) suggested in the open literature that lasers and AO systems would make a good match. Concurrent with the initial tests on the sky of both sodium (Thompson & Gardner 1987) and Rayleigh (Thompson et al. 1991; Thompson & Castle 1992) LGSs, Thompson and Gardner submitted proposals to the U.S. National Science

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