Adaptive Optics Infrastructure Development for High-contrast Science at Keck Observatory

Sam Ragland*†[1], Sylvain Cetre[1], Rebecca Jensen-Clem[2], Scott Lilley[1], Steph Sallum[3], Peter Wizinowich[1], Roberto Biasi[4], Jason Chin[1], Jacques Delorme[1], Charlotte Guthery[1], Nemanja Jovanovic[5], Eduardo Marin[1], Dimitri Mawet[5], Dietrich Pescoller[4], Avinash Surendran[1], and Ed Wetherell[1]

[1]W.M. Keck Observatory – United States
[2]UCSC – United States
[3]UCI – United States
[4]MICROGATE – Italy
[5]Caltech – United States

Abstract

W.M. Keck Observatory (WMKO) has endeavored to continually improve the capabilities of the Keck adaptive optics (AO) systems since first Keck AO science over two decades ago (1). We present the Keck AO infrastructure developments to enhance the high-contrast imaging capability and fully benefit from the next-generation high-contrast science instruments implemented or under development (i.e., SCALES (2) and HISPEC (3)) for Keck II AO. One of the development goals is to set a pathway towards detecting exo-Earths with ELTs.

This paper focuses on three ongoing developments, namely, (1) the new real-time controller (RTC (4)), (2) a new near-infrared pyramid wavefront sensor (PyWFS), (3) the High order Advanced Keck Adaptive optics (HAKA) project (5), and (4) the residual wavefront controller (rWFC (5)) developments, to enhance the high-contrast imaging capability at WMKO.

The new RTC, with its high performance and flexible capabilities, will enable the implementation of future algorithms and next-generation AO capabilities. We will present the on-sky performance of the new RTC commissioned on the Keck AO systems.

The new near-infrared PyWFS would improve the performance of future high-contrast imaging instruments, such as the SCALES and HISPEC, and enable new AO observing capabilities, such as LGS with NIR low-order wavefront sensing. We present the design of the new near-infrared PyWFS.

The HAKA project would upgrade the existing 349-actuator DM with a state-of-the-art 2900-actuator deformable mirror (DM) fabricated at ALPAO. We present the status of HAKA, including the design of the integration of the high-order DM with the new RTC, and the expected on-sky performance.

*Speaker
†Corresponding author: sragland@keck.hawaii.edu

Uncorrected residual wavefront errors limit the ultimate performance of AO systems, especially the raw contrast for high-contrast imaging studies. The recently proposed new AO subsystem, a residual wavefront controller (rWFC), to monitor the performance of the AO control loops and the image quality of the AO science instruments and apply the necessary changes to the telescope and AO parameters would minimize the residual wavefront errors. We present a scheme to integrate the rWFC with the operational software, including the new RTC.

The benefits of reducing or eliminating the residual wavefront errors has broad implications for optical astronomy besides high-contrast imaging. The lessons learned through the technology development will have implications for the ELTs. Testing these techniques on a segmented telescope will be extremely useful for teams developing high-contrast AO systems for all ELTs and future segmented space telescopes.

References:

(1) Wizinowich, P. et al., "Keck's Current and Future Roles as an ELT AO Pathfinder", 2023 (this conference)

(2) Skemer, Andrew J.; Stelter, R. Deno; Sallum, Stephanie; MacDonald, Nicholas; Kupke, Renate; Ratliff, Christopher; Banyal, Ravinder; Hasan, Amirul; Varshney, Hari Mohan; Surya, Arun; Prakaesh, Ajin; Thirupathi, Sivarani; Sethuram, Ramya; K. V., Govinda; Fitzgerald, Michael P.; Wang, Eric; Kassis, Marc; Absil, Olivier; Alvarez, Carlos; Batalha, Natasha; Boucher, Marc-André; Bourgenot, Cyril; Brandt, Timothy; Briesemeister, Zackery; de Kleer, Katherine; de Pater, Imke; Deich, William; Divakar, Devika; Filion, Guillaume; Gauvin, Étienne; Gonzales, Michael; Greene, Thomas; Hinz, Philip; Jensen-Clem, Rebecca; Johnson, Christopher; Kain, Isabel; Kruglikov, Gabriel; Lach, Mackenzie; Landry, Jean-Thomas; Li, Jialin; Liu, Michael C.; Lyke, James; Magnone, Kenneth; Marin, Eduardo; Martin, Emily; Martinez, Raquel; Mawet, Dimitri; Miles, Brittany; Sandford, Dale; Sheehan, Patrick; Sohn, Ji Man; Stone, Jordan, "Design of SCALES: a 2-5 micron coronagraphic integral field spectrograph for Keck Observatory," SPIE Proc. 12184, 121840I (2022).

(3) Mawet, D., Fitzgerald, M. P., Konopacky, Q., Jovanovic, N., Baker, A., Beichman, C., Bertz, R., Dekany, R., Fucik, J., Roberts, M., Porter, M., Pahuja, R., Ruane, G., Leifer, S., Halverson, S., Gibbs, A., Johnson, C., Kress, E., Magnone, K., Sohn, J. M., Wang, E., Brown, A., Maire, J., Sappey, B., Andersen, D., Terada, H., Kassis, M., Artigau, E., Benneke, B., Doyon, R., Kotani, T., Tamura, M., Beatty, T., Plavchan, P., Do, T., Nishiyama, S., Wang, J., Wang, J., "Fiber-fed high-resolution infrared spectroscopy at the diffraction limit with Keck-HISPEC and TMT-MODHIS: status update," SPIE Proc. 12184, 121841R (2022).

(4) Chin, J., Cetre, S., Wizinowich, P., Ragland, S., Lilley, S., Wetherell, E., Surendran, A., Correia, C., Marin, E., Biasi, R., Pataunar, C., Pescoller, D., Glazebrook, K., Jameson, A., Gauvin, W., Rigaut, F., Gratadour, D., Bernard, J., "Keck adaptive optics facility: real time controller upgrade," SPIE Proc. 12185, 121850V (2022).

(5) Ragland, S., Wizinowich, P., van Kooten, M., Bottom, M., Calvin, B., Fitzgerald, M., Hinz, P., Jensen-Clem, R., Mawet, D., Peretz, E.,"Residual wavefront control of segmented mirror telescopes," SPIE Proc. 12185, 121850Y (2022a).

Keywords: high contrast imaging, real time controller, high order deformable mirror, residual wavefront control, near infrared pyramid wavefront sensor