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A UV-visible prime focus camera for the Keck telescopes

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ABSTRACT

Many areas of astronomical research rely on deep blue wide-field imaging. Mauna Kea enjoys the very best UV transparency from the ground and the Keck telescopes with 10 meter f/1.75 primaries are well suited to a prime focus camera with a large angular field. Swinburne University leads a proposal to provide a camera (KWFI, for Keck Wide Field Imager) that is optimised in the UV but works well to 1µm wavelength. Keck has interchangeable top end modules, of which one is now unused and easily capable of housing the required corrector lens and detector enclosure. This paper concentrates on details of the KWFI optical design.

Keywords: Prime focus camera, wide field corrector, UV imaging

1. INTRODUCTION

Deep, wide-field images are needed to understand galaxy and stellar populations and to provide targets for long slit, multi-object, and IFU spectroscopy. KWFI is optimized for the relatively unexplored spectral range < 350 nm accessible from Mauna Kea, to give the Keck community a unique advantage following its world lead in UV spectroscopy (with LRIS) down to 305 nm. Deep, wide-field optical imaging has direct relevance and is complementary to TESS and future space-based missions WFIRST and EUCLID. In addition, KWFI will provide faint, rare targets, including lensed systems, for JWST and 30m-class telescopes.

A prime focus camera, with corrector design by Harland Epps, was originally included in Keck plans but was not made. The availabilities now of high performance two dimensional digital detectors and of an unused instrument module for a Keck top end have encouraged keen interest in reviving this intention.

2. COMPARISON WITH EXISTING AND PLANNED TELESCOPES

With its 10 meter primary mirror, all silica optics, and Mauna Kea site, KWFI's performance at and below 350nm will not be matched by any existing or planned competitor and its visible and near IR performance will also be competitive.

Of the 4m to 8m-class facilities with wide-field imagers, Subaru Hyper-SuprimeCam has no u-band throughput; CFHT Megacam's 3.6-m telescope aperture and glass optics limit its visible and especially its UV sensitivity; CTIO DECam has a 4-m aperture, moderate seeing and poor u-band throughput and is in the South; and LSST with 6.5-m effective aperture, has only half the u-band throughput and is in the South.

3. KECK INFRASTRUCTURE ENCOURAGING THIS PROJECT

A top end module that originally housed a chopping secondary is now unused and is stored on rails from which it can be rolled into the Keck top end, enabling a secondary/KWFI exchange in a few hours. Figures 1 through 3 indicate the relationship between this removable module and the telescope socket into which it can be fitted. The CAD model in figure 3 shows the top end socket (without its vanes that connect it to the telescope structure) with the module in place housing the corrector optical elements, including filters in two 6-position wheels.

Figure 4 shows how the optical components readily fit within a module. The load capacity of the top end socket is ~ twice the expected weight of KWFI

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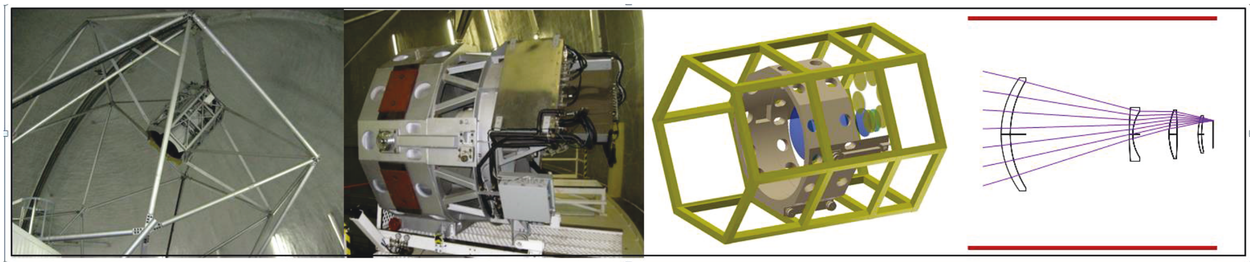

Figures 1 through 4. 1: Top end of Keck telescope. 2: A module rolled off the telescope, sitting on its storage rails. 3: CAD model of the top end socket with a module containing KWFI optics, rolled into its observing position. 4: Ray-trace through KWFI's four lens elements. The red lines indicate the limits of space within the removable module.

4. OPTICAL DETAILS AND PERFORMANCE

Figure 4 shows rays to the edge of the field with diameter 0.707° to cover a square field 0.5° (173mm) on a side. All elements are of silica, with the largest having an outside diameter of 1 metre. All surfaces are spherical except the concave one on the second element which is a prolate ellipsoid. The field is flat with the average scale ~ 97 µm/arcsec, giving a good match to CCD pixels ~ 15 µm square.

An atmospheric dispersion corrector (ADC) has been designed with all silica elements but it would require an additional lens element and special mechanisms for its control. It is recommended to cope without an ADC by splitting the **u** passband, represented by wavelengths 327, 351, and 370 nm into **u1** (327 to 345 nm) and **u2** (342 to 370 nm). Taking the best case (1 percentile) Keck seeing at 650 nm wavelength as 0.4 arcsec FWHM and allowing for the increase in seeing at shorter wavelengths and larger zenith distances, the equivalent rms radii of images in **u** were calculated as 0.23, 0.25, and 0.35 arcsec at zenith distances (ZDs) 0, 30°, and 60°, respectively. The rms criterion for assessment was chosen because convolution with the optical design values is then better behaved than with FWHM.

Figure 5 shows plots of the percentages of the field area within which the designed rms radii are less than the values on the X axis for the three ZDs. For comparison, dashed lines are located at the radii equivalent to the 1 percentile seeing. Even with this unusually good seeing, there is little loss of resolution with the whole **u** bandpass at ZD 0 or 30°, but significant loss at ZD 60°. However, for **u1** and **u2**, the worst images in the field, even at ZD 60°, are degraded very little. So it is apparent that there will be little harm in omitting an ADC if filters are available to split the **u** window.

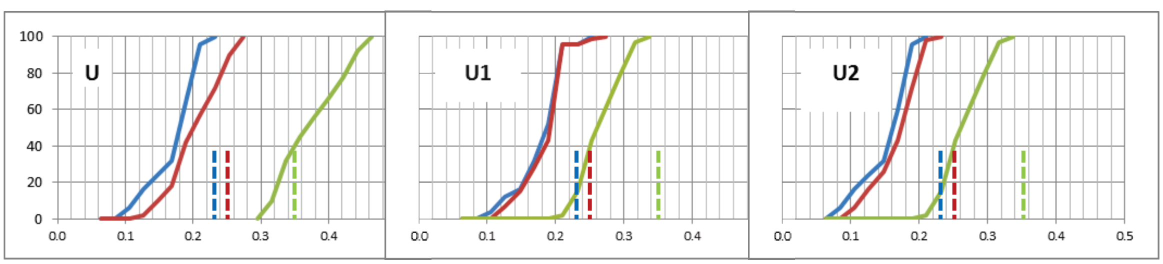

Figure 5. Plots of percentages of the field area for which the rms image radius is less than the value (arcsec) on the X axis for the three ZDs 0, 30, and 60 deg represented in blue, red, and green. The dashed lines indicate the 1percentile seeing for these ZDs.

There is an aim to have both Keck telescopes always available for spectral observations on targets of opportunity. With KWFI in place, a grism mounted in a filter wheel could provide very low resolution spectra at short notice.

5. CONCLUSION

KWFI will have unequalled UV performance and it will be relatively inexpensive, comparable in cost to CFHT's Megacam rather than Subaru's Hyper-SuprimeCam, through the simplicity of its optical design and the existence already of much of the infrastructure to mount it onto a Keck telescope. A larger field would be possible but with steeply increasing cost for the optics and CCDs. Omitting an ADC is shown to have little effect on performance, while avoiding significant additional cost.