Draft version April 25, 2019
Typeset using LATEX default style in AASTeX62

FIDDLES: Fibers in DEIMOS demonstrating light extraction and stability

(Received; Revised; Accepted)

Submitted to AJ

1. MOTIVATION

We want to test the performance of coupling of a fiber imaging system to the focal plane of a slow (f/15) telescope in preparation for building FOBOS for Keck.

Originally we proposed to do this by constructing and testing a test-bench assembly at UCO and then designing a system that can be slotted into the mask holder in DEIMOS. However, there will be very limited time that we can perform this experiment at Keck, and we would like to have observations from another telescope as a relative comparison; e.g., how much does our understanding of the focal plane affect our ability to couple fibers to it. APF would be good for this, if we can get some engineering time on it.

2. SIGNAL-TO-NOISE CALCULATION

I have done some initial S/N calculations for the fiber near-field profile as measured by FIDDLES mounted on both Lick/APF and MaunaKea/Keck.

Inputs & Assumptions:

- For the source, I use a reference spectrum with a constant AB magnitude (i.e., constant F_ν) normalized to a given g-band magnitude. I adopt the "no atmosphere" response functions for the g-band filter for sDSS taken from http://www.sdss.org/wp-content/uploads/2017/04/filter_curves.fits.
- I assume we take both on- and off-source (sky-only) observations, where the source is a point source with a Gaussian point-spread function. These could be dithered or simultaneous; however, I have also assumed that I can perfectly subtract the off-source flux from the the on-source observation (see below).
- The Maunakea sky spectrum is approximated by taking an observed dark-sky spectrum observed by MaNGA and rescaling it to match a DEIMOS dark-sky spectrum over the same wavelength range. The dark-sky surface brightness of the spectrum is $\mu_g = 22.14$ mag/arcsec^2.
- For bright-sky conditions, I just scale the dark-sky spectrum up by 3 mag. This is not correct in that the bright-sky spectrum is certainly **not** just a scaled up version of the dark-sky spectrum. However, this was the simplest thing to do for now. Scaling up by 3 mag may also be a bit extreme.
- I adopt the Maunakea atmospheric transmission curve used in the IDL-based Keck ETCs.
- I adopt the same sky emission and attenuation for both Lick and Maunakea; light pollution is more significant at Lick meaning that the S/N estimates at Lick are likely overestimates, at least in dark conditions.
- I assume the FIDDLES system performs identically at APF and Keck.
- I assume the fiber perfectly scrambles the light in the output near-field.
- I assume the off-source near-field image can be perfectly subtracted from the on-source image.
- I assume there is no scattered light in the system.
- The telescope properties relevant to the calculation that I assumed are in Table 1. The telescope-specific and generic properties of FIDDLES are provided in Table 2.

Table 1. Telescope Properties

	APF	Keck
Effective Area (m^2)	4.47	72.37
Plate Scale (mm/arcsec)	0.175	0.725
Focal Ratio	15	15

- I assume microlens foreoptics convert the telescope f/15 beam to f/3 for input to the fiber, that there are no coupling losses, and that there is no focal-ratio degradation.
- The fiber attenuation is taken from a WFOS spreadsheet with a 10m fiber run of a Polymicro fiber.
- I assume the near-field image is a perfectly in focus with no image-quality degradation by the imaging optics or camera.
- I use the measurements of the detector properties provided by Molly for the test-bench camera.
- I adopt the quantum efficiency curves from https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=7900 for their 4-megapixel monochrome camera.

S/N calculation comments:

- The detector QE and filter are killer efficiency hits. We probably don't care for this experiment, though. I thought astro-grade detectors had efficiencits of more like 90%, and it's worth noting Thorlabs has filters that are 400 Åwide, but with peak efficiencies of ∼75%.
- There is enough overlap between Keck and APF in the S/N plots that we could feasibly observe the same stars in both (albeit with the Keck observation at much higher S/N at fixed m_g.)

Considerations for development of FIDDLES and observing plan:

- We want to directly measure the point-spread function during the observations.
- We want to measure both the near and far-field output of the fiber; these S/N calculations are for the near-field only. I have not tried to simulate the far-field.
- We want to observe with different angles with respect to the moon to estimate scattered-light effects.
- We need to consider how differential atmospheric refraction may affect the observations (e.g., acquisition and guiding).

Table 2. FIDDLES Properties

Property		
Readnoise (e−)	6.45	
Dark Current (e−/s)	5	
Full-Well (e−)	18133	
Pixel size (μm)	7.4	
Fiber diameter (μm)	150	
IO Focal Ratio	3	
	APF	Keck
Pixel scale (arcsec/pixel)	0.212	0.051
Fiber diameter (arcsec)	4.30	1.03
Aperture Efficiency ($0\farcs8$ seeing)	1.0	0.69

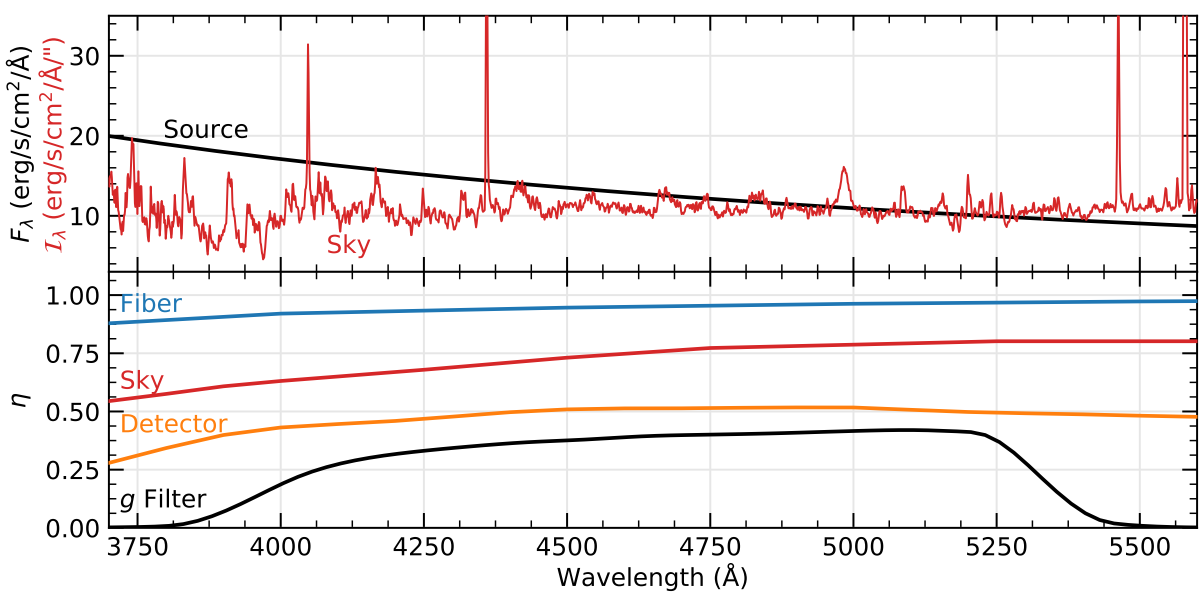

Figure 1. Example components of the S/N calculation. *Top* — The surface brightness of the sky after artificially scaling up a dark-sky spectrum by 3 g-band magnitudes (red) and the reference spectrum (constant F_ν) with $m_g = 18$ used to describe the spectrum of the source. *Bottom* — The effeciency of various components of the observation, including the fiber (blue), sky (red), detector quantum efficiency (orange) and g-band filter.

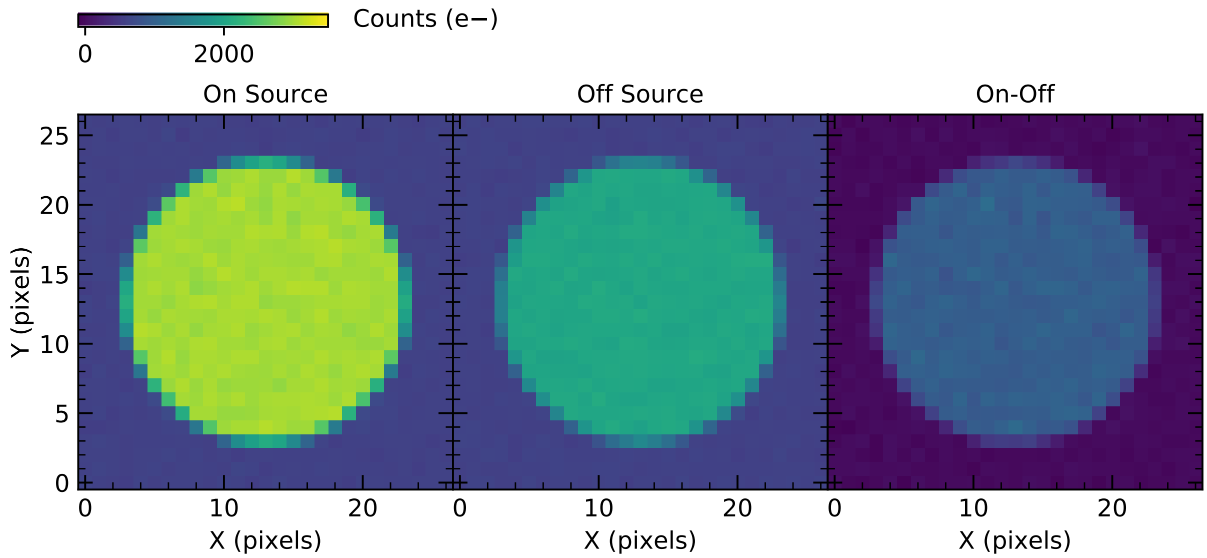

Figure 2. Example realization of the output near-field image both on (left) and off (middle) the point source, as well as the difference between the two (right). The S/N calculations provide the S/N per pixel in the brightest part of the right image. The realization is for an 18th magnitude star observed by Keck under bright conditions, directly comparable to the data provided in Figure 3.

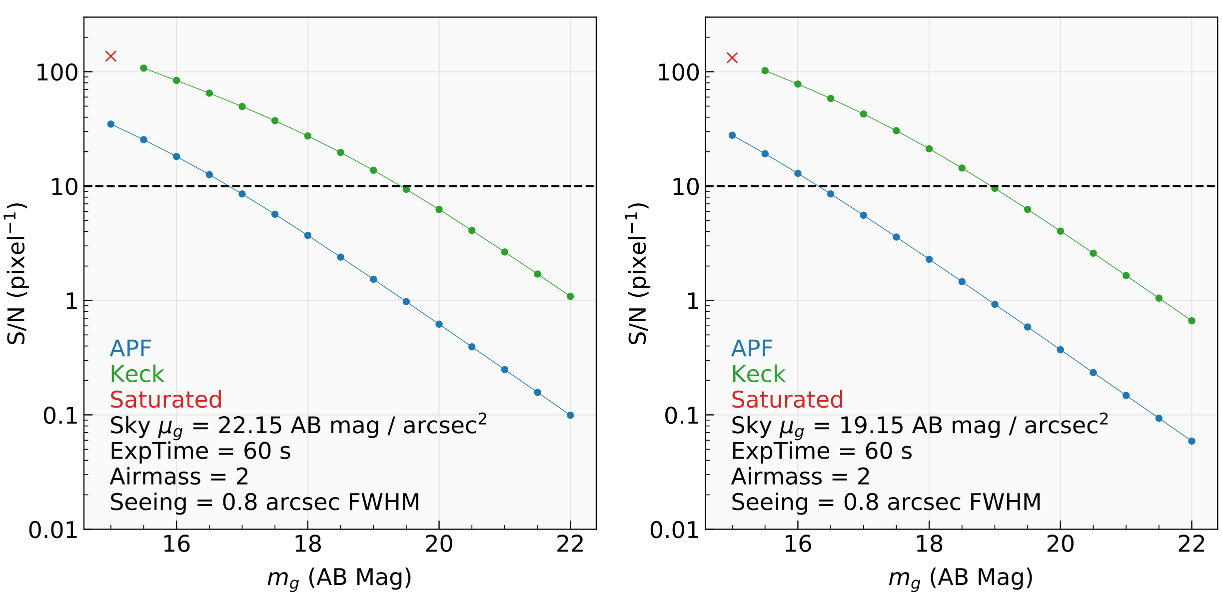

Figure 3. S/N estimates in the brightest part of the near-field difference image (see Figure 2) as a function of point source g-band magnitude; the left panel assumes dark sky conditions, whereas the right panel artificially amplifies the dark-sky spectrum by 3 magnitudes. Results are shown for both APF (blue) and Keck (green) observations; the observation of the 15th magnitude star at Keck should saturate the current test-bench detector in a 60 second integration.