# Preliminary Design of the iLocater Acquisition Camera for the LBT

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## Introduction

Existing radial velocity (RV) instruments for planet detection are limited by systematic errors resulting from their seeing-limited design. iLocater, an ultra-precise spectrometer that operates at the diffraction limit, has been officially approved for installation at the Large Binocular Telescope (LBT) and will search for Earth-like planets orbiting the nearest stars. The instrument utilizes the "extreme" adaptive optics (AO) system of the LBT to reduce spatial variations of light caused by atmospheric turbulence (Esposito et al. 2011) as shown in Figure 1. This corrected light will be coupled into single-mode fibers and input into an ultra-stable spectrograph (Y-band at 0.95-1.1μm) optimized for detecting Earth-like planets around infrared emitting M-type stars. Scheduled for commissioning in 2017, iLocater will coincide with the launch of the Transiting Exoplanet Surveying Satellite (TESS).

We present the preliminary design and laboratory testing for iLocater's acquisition camera to couple starlight from the telescope into optical fibers. Our design uses the combined (incoherent) beam from both LBT dishes to reduce photon-noise limited errors to below 20 cm/s for bright stars.

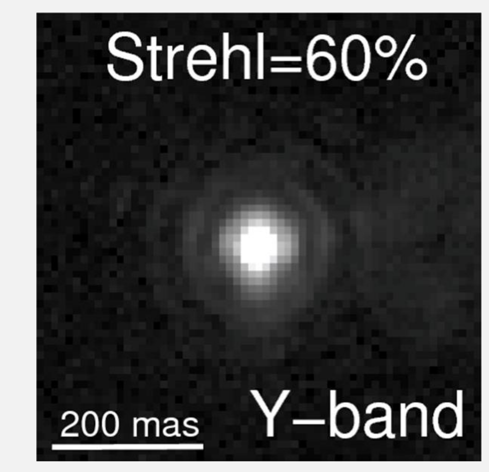


Figure 1: An AO corrected image from the LBT.

## Science Cases

- Follow-up observations for the TESS space mission
- Study of planets in binary star systems
- Measurements of spin-orbit angles for terrestrial worlds
- Discovery of nearby Earth-like worlds
- Radial velocity measurement of the youngest exoplanets
- Characterize atmospheres of Super-Earths

Further information can be found at **www.iLocater.nd.edu.**

## Optical Design

Light from the twin dishes of the LBT can be diverted into the Large Binocular Telescope Interferometer (LBTI) which provides wavefront measurement for the LBT AO system. The steering optics of LBTI are used to divert the light from each telescope dish into a separate acquisition system used to couple starlight into single-mode fibers.

As shown in Figure 2, collimated near-infrared light enters the acquisition system from the left. The Y-band light required for radial velocity measurements is reflected by a dichroic and focused onto a mirror-mounted fiber. This allows the efficient coupling of light. The back-reflected beam from the fiber-face is imaged onto a back-reflection camera allowing a verification of coupling and imaging of companion objects.

To maintain a good coupling of light, J-band light from the telescope is passed to a finder and guiding camera which maintains the location of the peak of the PSF within the field using a tip-tilt mirror (not shown).

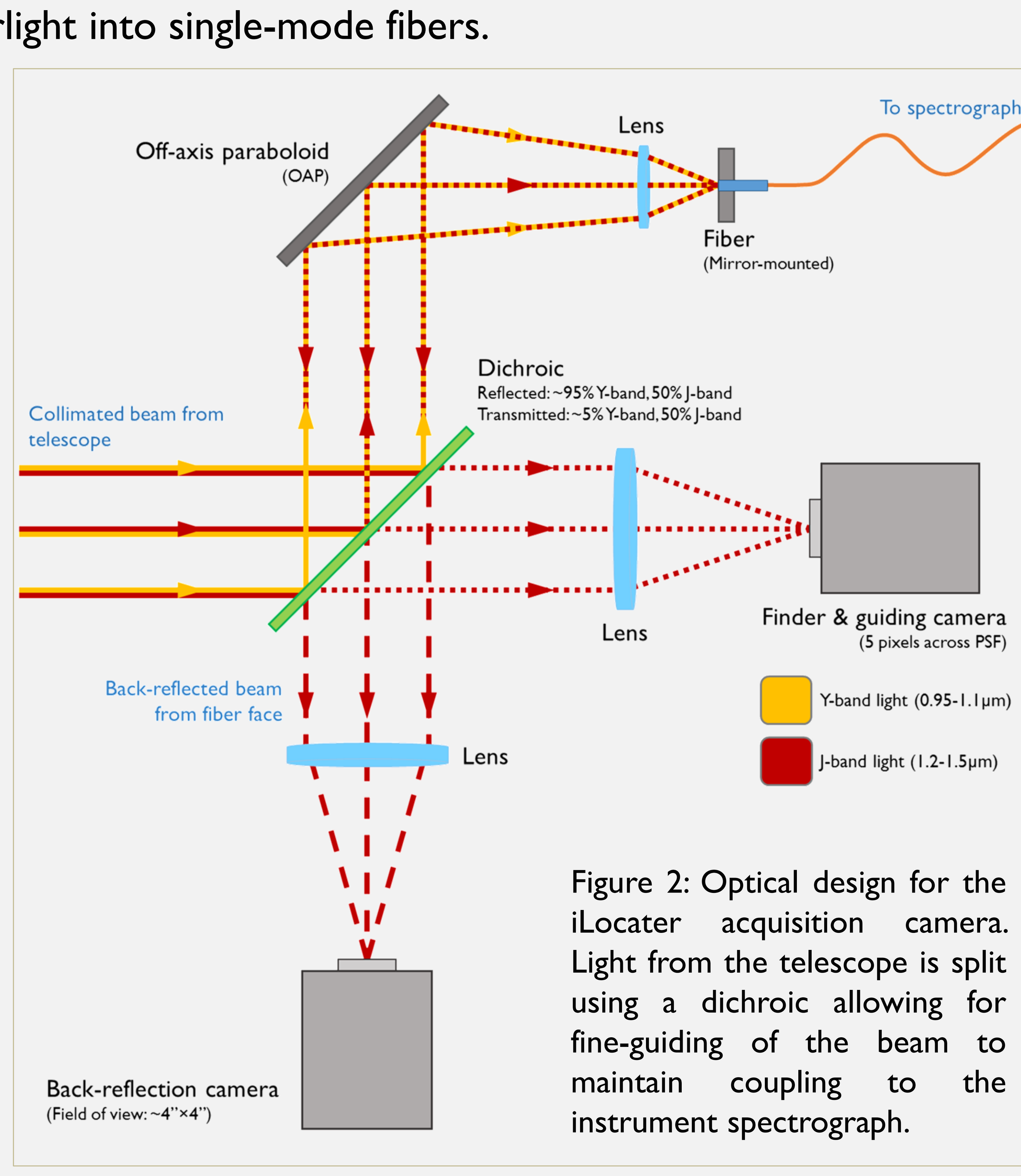


Figure 2: Optical design for the iLocater acquisition camera. Light from the telescope is split using a dichroic allowing for fine-guiding of the beam to maintain coupling to the instrument spectrograph.

### Single-Mode vs. Multi-Mode Fibers

Current Doppler spectrometers on seeing-limited telescopes are fed using multi-mode fibers. These fibers can be coupled more easily than single-mode fibers due to their increased diameter, however, they introduce a temporally varying spatial intensity distribution (modal noise) at their output leading to systematic errors in RV measurements (Jovanovich et al 2014). By using an AO corrected beam, very small single-mode fibers can be used, effectively eliminating the source of modal noise, facilitating a spectrometer capable of RV measurements in the sub-meter/second range (Crepp 2014). Laboratory testing at the University of Notre Dame has achieved 70% coupling efficiency with monochromatic light.

## LBTI

iLocater will use the existing infrastructure of the Large Binocular Telescope Interferometer (LBTI) to deliver light to its acquisition camera. The LBT AO system has demonstrated the ability to deliver Y-band images with a 60% Strehl-ratio (Figure 1). This allows for efficient coupling of starlight into single-mode fibers.

Two possible locations within the instrument (shown in Figure 3) are being studied as to their feasibility for mounting the acquisition camera:

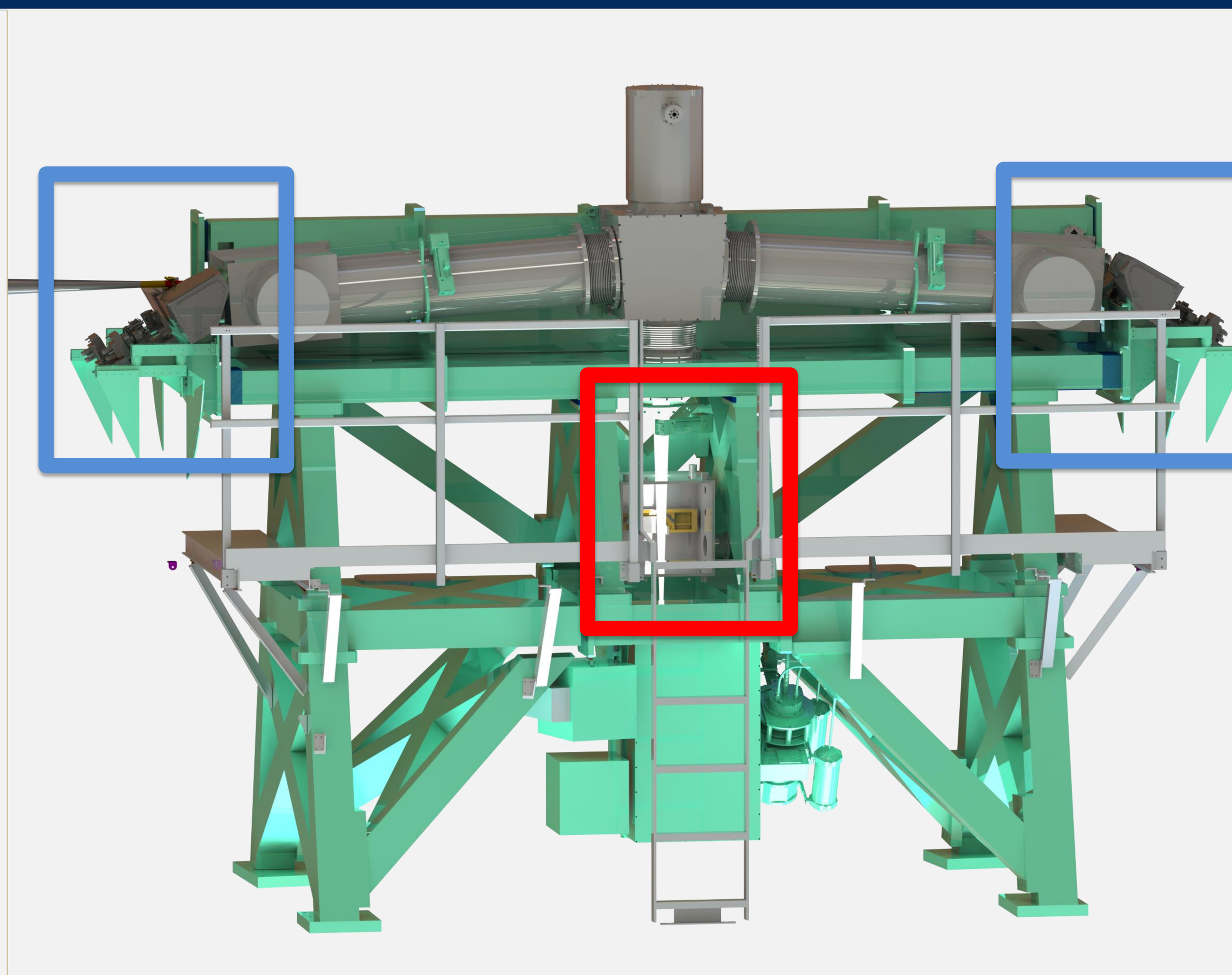

Figure 3: LBTI structure showing the possible sites for the location of the acquisition camera. The sites shown in blue intercept the telescope beam before the LBTI vacuum chamber while the site in red is at the focal plane of the instrument.

1. Mounting at the beginning of the LBTI enclosure with two separate acquisition cameras.
2. A new instrument port being created at the combined focus of LBTI where a single acquisition camera would be used to couple starlight from the two telescopes into separate fibers.

## Acquisition Camera Design

The design of the LBT means that all instruments experience a change in their gravity vector during operation. To minimize this effect within the acquisition camera, iLocater uses a cage mount system to house its optical components as shown in Figure 4.

The layout shown matches that of the optical design in Figure 2. Light enters from the telescope on the left and is reflected off a tip-tilt mirror used to maintain the coupling of starlight into the fiber. The two cameras shown are both infra-red devices used for science imaging and guiding for the tip-tilt mirror.

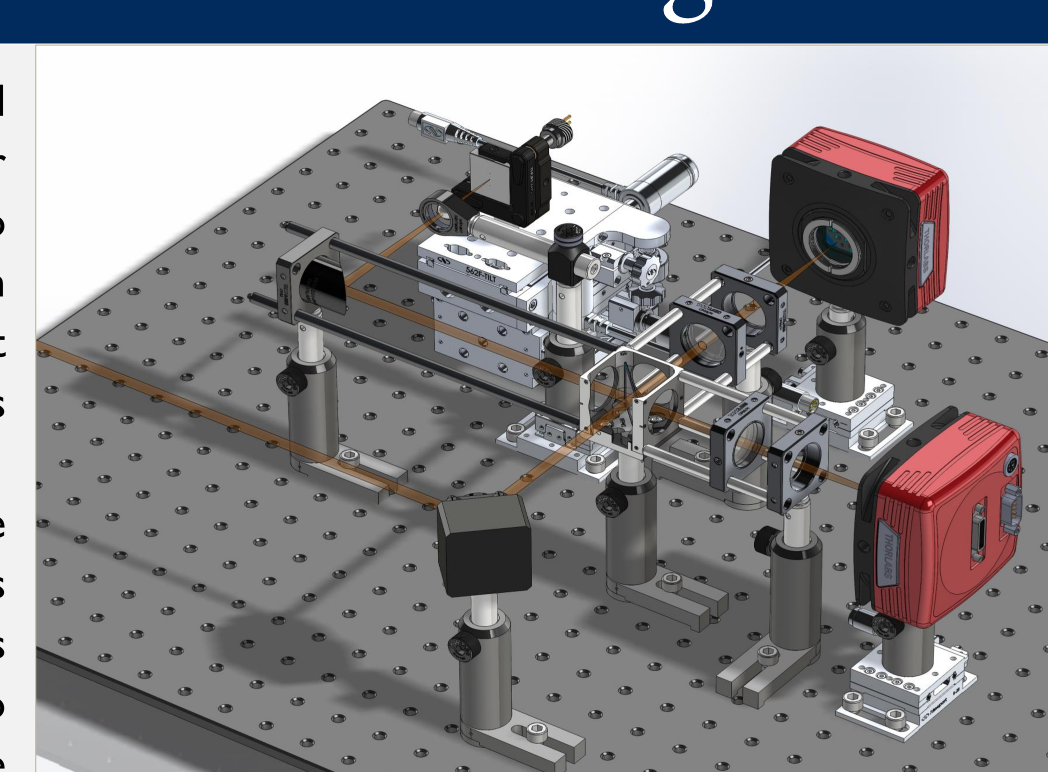

Figure 4: The structure of the iLocater acquisition camera. Light enters from the telescope and is split by wavelength using a cube-mounted dichroic.

The mirror-mounted fiber is located on a 5-axis piezoelectric driven stage (Figure 4: shown in grey). Having the ability for ultra-precise fiber positioning is vital for effective high-efficiency coupling.

## Future Work

1. The addition of phase-induced amplitude apodization (PIAA) optics within the fiber channel of the acquisition camera would further increase coupling efficiency.
2. By adding a Lyot stop before the back-reflection camera, the fiber may act as a coronograph. This novel design makes it possible to obtain simultaneous RV and high-contrast imaging data.

## References

- Crepp, J., *Science* 346, 6211 (2014).
- Esposito, S. et al., *Proc. SPIE* 8149 (2011).
- Jovanovic, N. et al., *Proc. SPIE* 9147 (2014).

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