The NEID precision radial velocity spectrometer: Commissioning of the Port Adapter

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Introduction

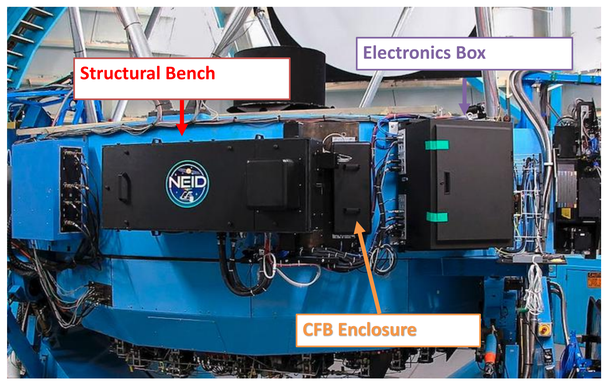
In October 2019, the NEID instrument (PI Suvrath Mahadevan, PSU) was delivered to the WIYN 3.5 m Telescope at Kitt Peak National Observatory. Commissioning began shortly after delivery, but was paused due to a COVID-19 imposed observatory shutdown in March 2020. The observatory has recently reopened and NEID commissioning has resumed.

NEID is an optical (380-930 nm), fiber-fed, precision Doppler radial velocity system developed as part of the NASA-NSF Exoplanet Observational Research (NN-EXPLORE) partnership. While the spectrometer and calibration system are maintained in a highly controlled environment on the basement level of the WIYN, the NEID Port Adapter mounts directly to a bent-Cassegrain port on the telescope and is responsible for precisely and stably placing target light on the science fibers. Here we present a brief overview of the as-built Port Adapter and its sub-components, which include four cameras for acquisition, guiding, and precision triangulation on both a high-resolution (R~120,000) and high-efficiency science fiber head. We then discuss preliminary on-sky performance compared to requirements as well as next steps as we complete commissioning.

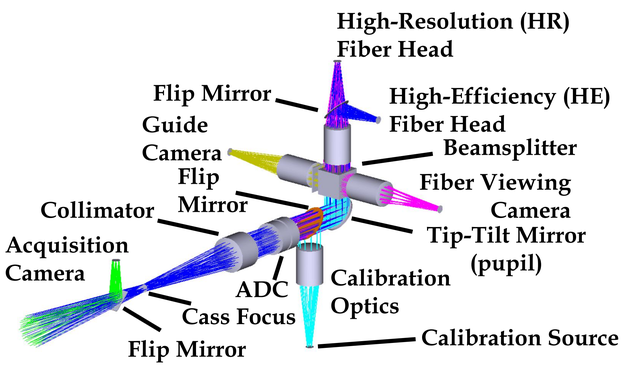
Port Adapter Key Functionalities

Function	Subassembly
Acquire the target star	Guide Camera (90″ FOV)
Stabilize the target star position	Tip/Tilt Mirror + Guide Camera
Correct for atmospheric dispersion	Atmospheric Dispersion Corrector (ADC)
Maintain telescope focus	Guide Camera + Toroidal Lens (Coming Soon)
Calibration source injection	Calibration Assembly
Real-time sky monitoring	Coherent Fiber Bundle (CFB) Imager
Image the fiber bundles	Fiber Viewer Camera

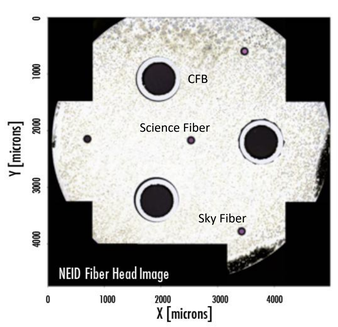
Port Adapter Component Overview



Component	Contents
Structural Bench	Main optical assembly including: 3 cameras, ADC, tip/tilt mirror, calibration and solar light injection unit
CFB Enclosure	Optics and camera for imaging 6 coherent fiber bundles (CFBs)
Electronics Box	Computer, power supplies, and controllers



See Schwab et al. 2018 and Logsdon et al. 2018 for more details on the opto-mechanical design



Profilometer image of a NEID fiber head adapted from Roy et al. (2020).

A dedicated assembly images the six NEID CFBs (3 from each Fiber Head). CFBs preserve spatial information over a larger FOV than a single fiber (5.6″ vs 0.92″ in HR fiber). The CFBs allow us to:

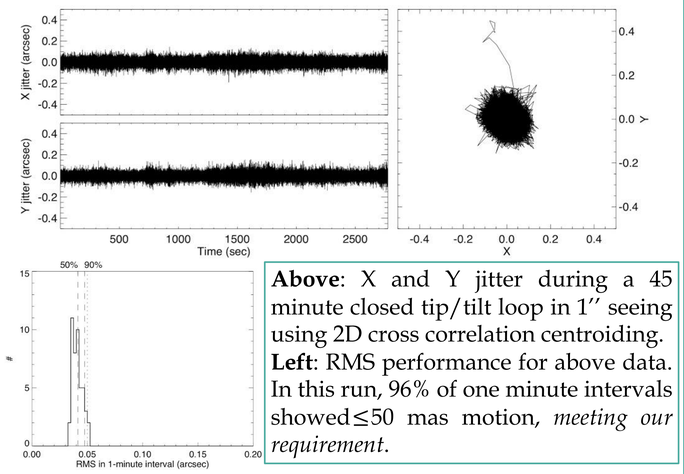
1. Precisely locate the position of the science fiber in each head.
2. Provide real-time sky background monitoring (see Roy et al., 2020 for more details)

The NEID instrument is funded by the NN-EXPLORE program. The WIYN 3.5 m Telescope is a partnership of Indiana University, University of Wisconsin, The Pennsylvania State University, University of Missouri-Columbia, Purdue University, University of California Irvine, NSF and NASA.

Tip/Tilt Guiding

Performance Requirement:
The Port Adapter guiding system must maintain the RMS centroid of the stellar PSF on the science fiber to within 0.05″ (3.4 μm) of the center of the fiber for 90% of 1-minute intervals under median seeing (0.8 arcsec) and wind conditions with a V_{mag}= 12 star or brighter.

Closed-Loop Design:
- Guide camera imaging at 50 Hz
- User-specified centroiding algorithm
- Fast steering, tip/tilt mirror correction
- Outer Loop: Telescope drift correction



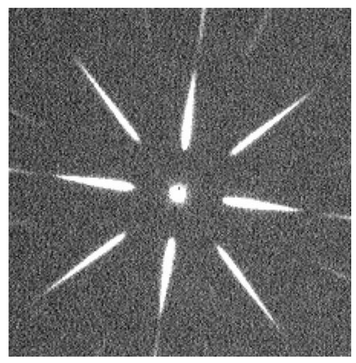
Above: X and Y jitter during a 45 minute closed tip/tilt loop in 1″ seeing using 2D cross correlation centroiding. **Left**: RMS performance for above data. In this run, 96% of one minute intervals showed ≤50 mas motion, *meeting our requirement*.

Also see Poster 11447-277 for details on telescope vibration mitigation

Atmospheric Dispersion Correction

Performance Requirement:
The peak/valley displacement error due to atmospheric dispersion within the NEID bandpass shall not exceed 0.1 arcseconds for zenith angles from 0° to 58°, and shall be better than 0.2 arcseconds down to a zenith angle of 71°, within the central 5″ FOV.

Design and Preliminary Operation:
- Two Amici prisms (Schwab et al., 2018)
- Automated to rotate every 10s based on zenith distance using look-up table



In addition to our ADC prisms, the Port Adapter includes a Ronchi grating that is deployable in front of the guide camera (see on-sky image at left). Once fully commissioned, this grating will enable us to precisely calibrate the ADC by measuring and correcting for residual atmospheric dispersion similar to Pathak et al. (2016, 2018).

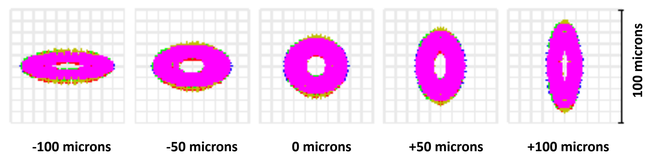
Also see Poster 11447-292 for details on ADC development and verification

Realtime Focus Monitoring with Toroidal Lens

Performance Requirement:
The Telescope must achieve and maintain focus of the beam at the science fiber to ±30 microns under median seeing and wind conditions with V ≤ 16 mag stars.

Current Operation:
- Manual secondary mirror focus sweeps taken periodically through the night
- Automatic focus adjustments via temperature vs focus look-up table
- NEID Queue Observers manually implement minor focus adjustments during observations, if needed

Coming Soon!



Above: Zemax spot diagrams of our toroidal lens design. If our target is in focus, the spot will be circular, otherwise the spot is elongated.

The toroidal lens will be installed on a removable stage in front of the guide camera and has several advantages over our current focusing scheme including:
- Eliminates need for focus sweep
- Uniquely measures intra- and outra-focus spots

Current Status and Next Steps:

- Commissioning of the NEID Port Adapter resumed in November 2020, and is nearing completion.
  - Toroidal lens is expected to arrive at WIYN in early 2021.
- NEID Spectrometer commissioning is scheduled to resume in December and is expected to be completed in 2021A.
- NEID will be run in queue mode with queue commissioning happening simultaneously with spectrometer commissioning (also see *Poster 11449-116* for more details on the queue). Three NEID Queue Observers are on staff at WIYN and are commissioning the instrument.
- Shared risk science time is scheduled for late-2020B, with full science operations expected in 2021A.
- A new call for proposals for 2021B is expected in Spring 2021.

For more information see talks/posters: 11447-245 (NEID Overview), 11447-270 (NEID Solar Feed), 11447-276 (NEID Ghost Mitigation), 11447-304 (RV drift correction), 11447-318 (NEID Fiber Injection System)
websites: http://www.wiyn.org; http://www.neid.psu.edu/