FY23 Strategic Initiatives Research and Technology Development (SRTD)

Compact Adaptive Optics for Extreme Precision Radial Velocity

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Strategic Focus Area: Extreme Precision Radial Velocities | **Strategic Initiative Leader:** Charles Lawrence

Project Objective:

- Enable a key technology – compact adaptive optics (CAO) – for increasing the discovery of Earth-like exoplanets.
- This will:
  1) radically reduce the size, mass and cost of adaptive optics
  2) shrink the mass and volume of high-resolution spectrographs
  3) enable wide deployment and
  4) increase exoplanet yields

Background:

- Precision radial velocity is key to ground-based exoplanet detection.
- Extreme precision radial velocity (EPRV; RV precision of <10 cm/sec) is the only method for detecting exoEarths.
- High-resolution single-mode spectrographs have the potential to achieve this precision.
- Adaptive optics is required for efficient fiber coupling into these instruments.

Significance to JPL and NASA:

- Ground-based precision radial velocity measurements support NASA science mission objectives for: 1) target identification, 2) follow-up validation and characterization, and 3) mass and orbit determination.
- The need to complete the census of neighborhood stars down to Earth masses, along with follow-up of planetary candidates from NASA transit missions such as *Kepler* and *TESS*, are dramatically increasing the need for ultra-precise Doppler technology
- These NASA missions include Kepler, TESS, JWST, Roman, and future Habitable Worlds Observatory missions

Approach and Results:

- We successfully designed, fabricated, assembled, aligned and tested the compact AO system.
- The key parts of the AO system – the deformable mirror and the Pyramid wavefront sensor - are operational.
- Integrating these together to control wavefront is next.

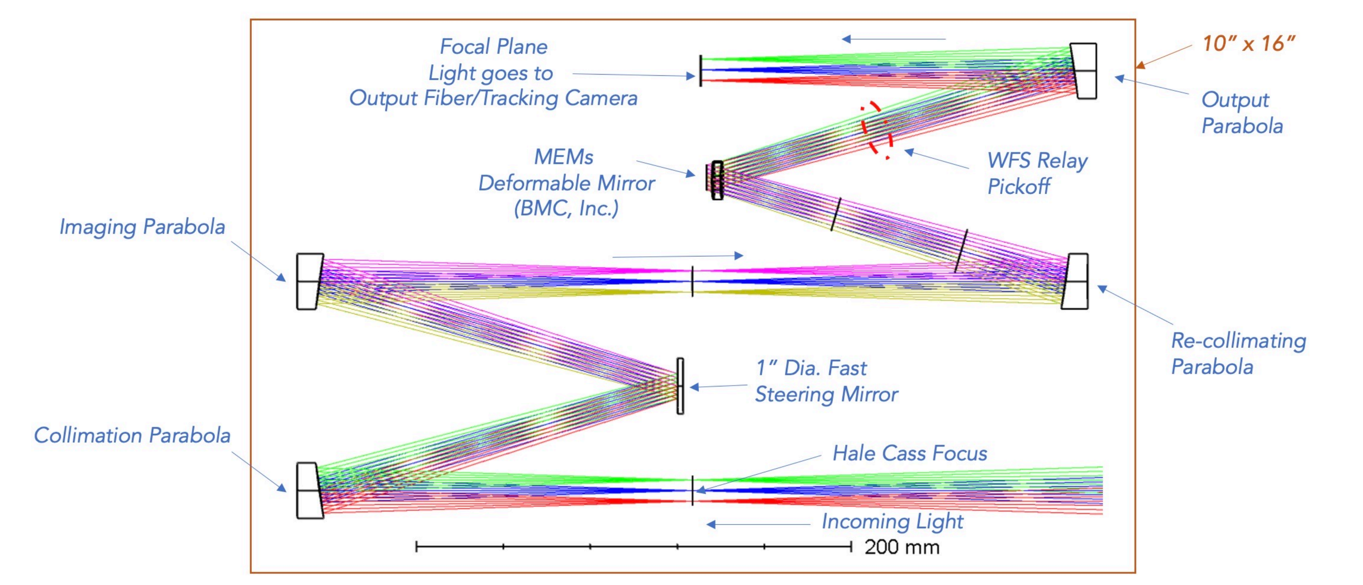

Figure 1. This diagram illustrates the optical design of the fast-steering mirror/deformable mirror relay. This two-mirror relay creates two pupils, two intermediate focal planes and has a large field of view.

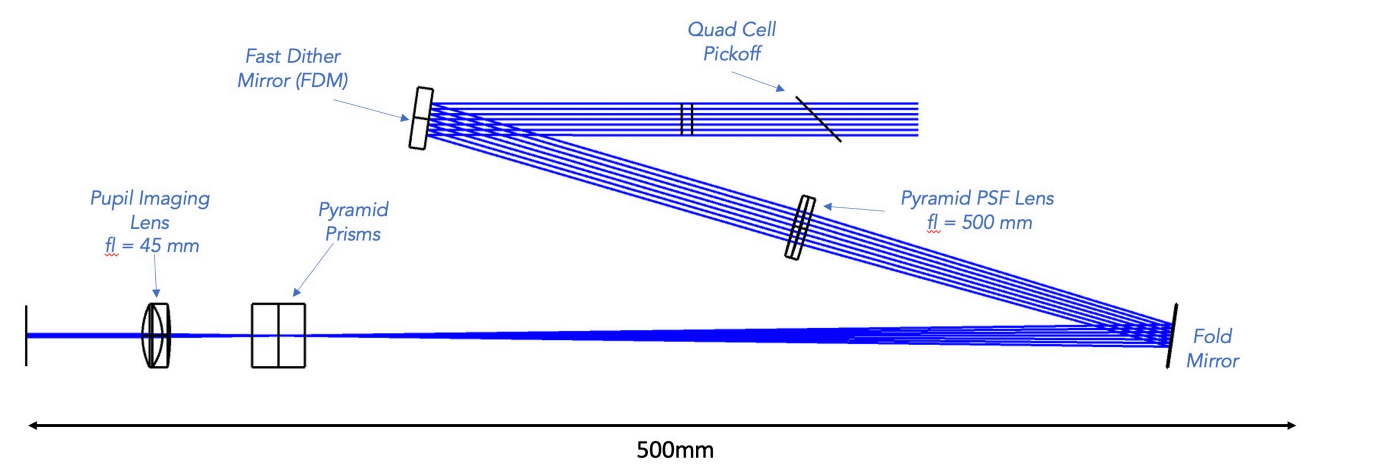

Figure 2. This diagram illustrates the optical design of the wavefront sensor relay. Light enters as a collimated beam where it reflects of the fast dither mirror – located at a pupil. Upon reflection light passes through a long focal length lens which forms a focal spot on the pyramid optics.

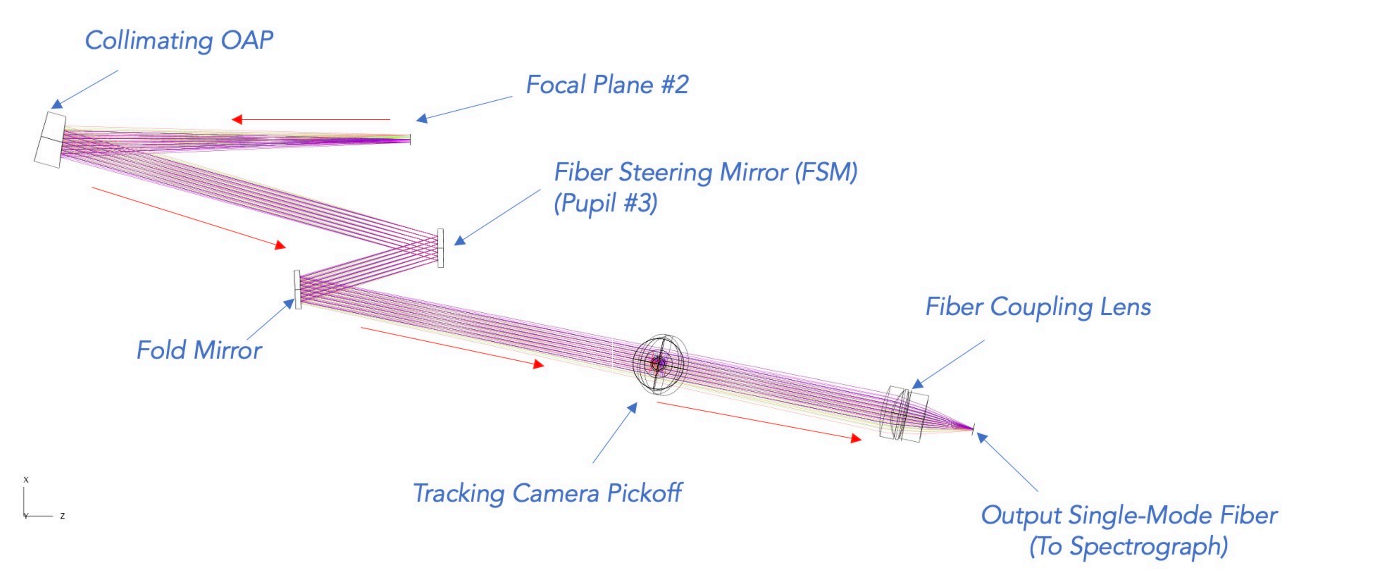

Figure 3. This diagram shows how light is coupled into a single-mode fiber using the fiber-coupling relay. The steering mirror is a tip/tilt stage with fine resolution. This enables coupling into a single-mode fiber very accurately.

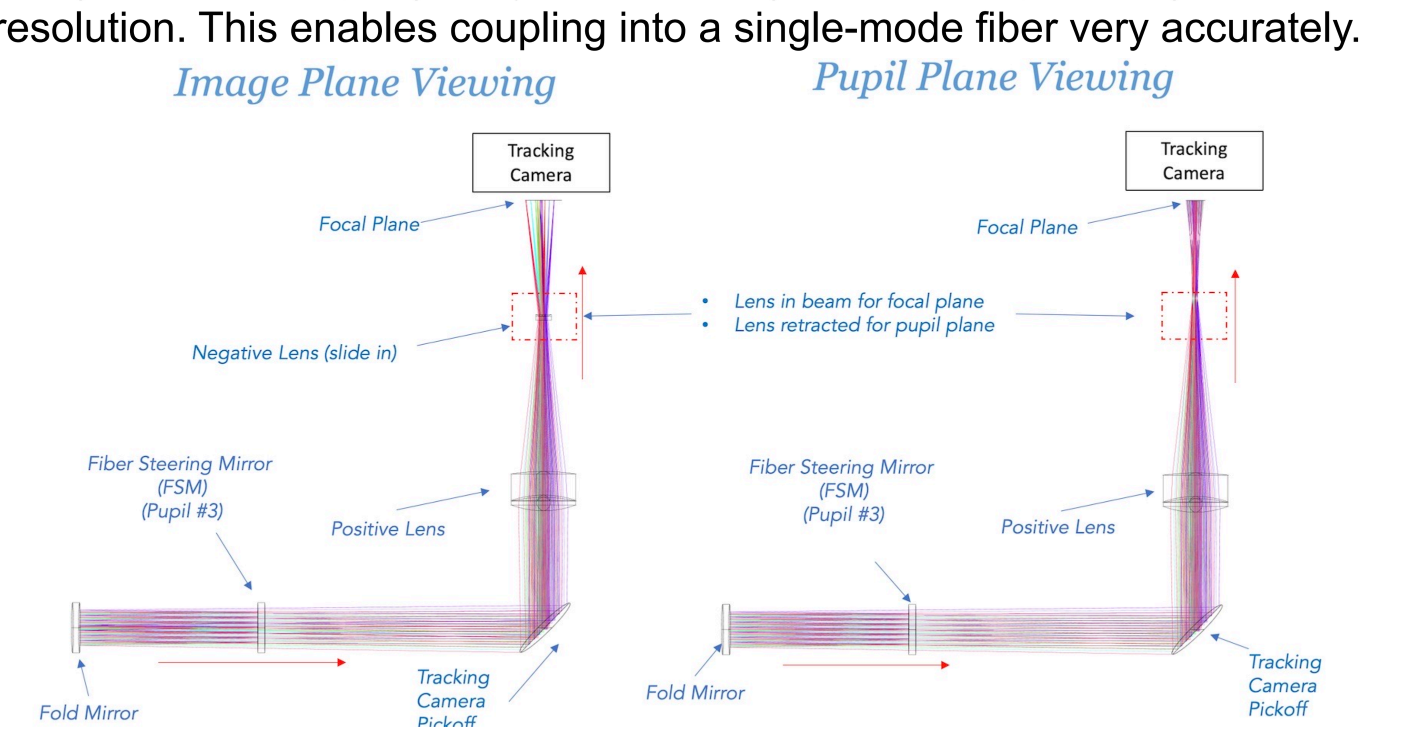

Figure 4. The tracking camera relay has two modes: focal plane viewing and pupil plane viewing. Light is picked off from a beamsplitter and directed towards the tracking camera. A motorized translation stage with a negative lens enables the two selectable modes.

Publications:

[A] Walter, A., Wallace, J. K., Noyes, M., Roberts, L., and Serabyn, E., "Compact adaptive optics real-time system design for extreme precision radial velocity measurements at palomar telescope," Proc. SPIE (2023).

[B] Wallace, J. K., Walter, A., Noyes, M., Roberts, L., and Serabyn, E., "Design and Development of Compact Adaptive Optics Instrumentation for Extreme Precision Radial Velocity," Proc. SPIE (2023).

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