The Large Fiber Array Spectroscopic Telescope: Fiber-feed Fabrication and Characterization

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WHAT IS LFAST

The **Large Fiber Array Spectroscopic Telescope (LFAST) project** seeks to construct large arrays of small, individual fiber-fed telescopes for very high resolution spectroscopy, as proposed by Angel et al., 1977. To study the technical requirement for LFAST, we are currently building a 20x telescope mount prototype (Fig.1). Our goal is to replicate this system to form an array with collecting area comparable to planned ELTs (e.g., 132 mounts, providing a collecting area of 1200 m^2) and feed optical and infrared spectrographs with resolution 10^4-10^5. **This array requires thousands of optical fiber feeds. We are developing tools and techniques to fabricate fibers while maintaining affordability and consistency in high quality.** In this poster, we describe our efforts to mass produce and test optical fibers for our prototype and future arrays.

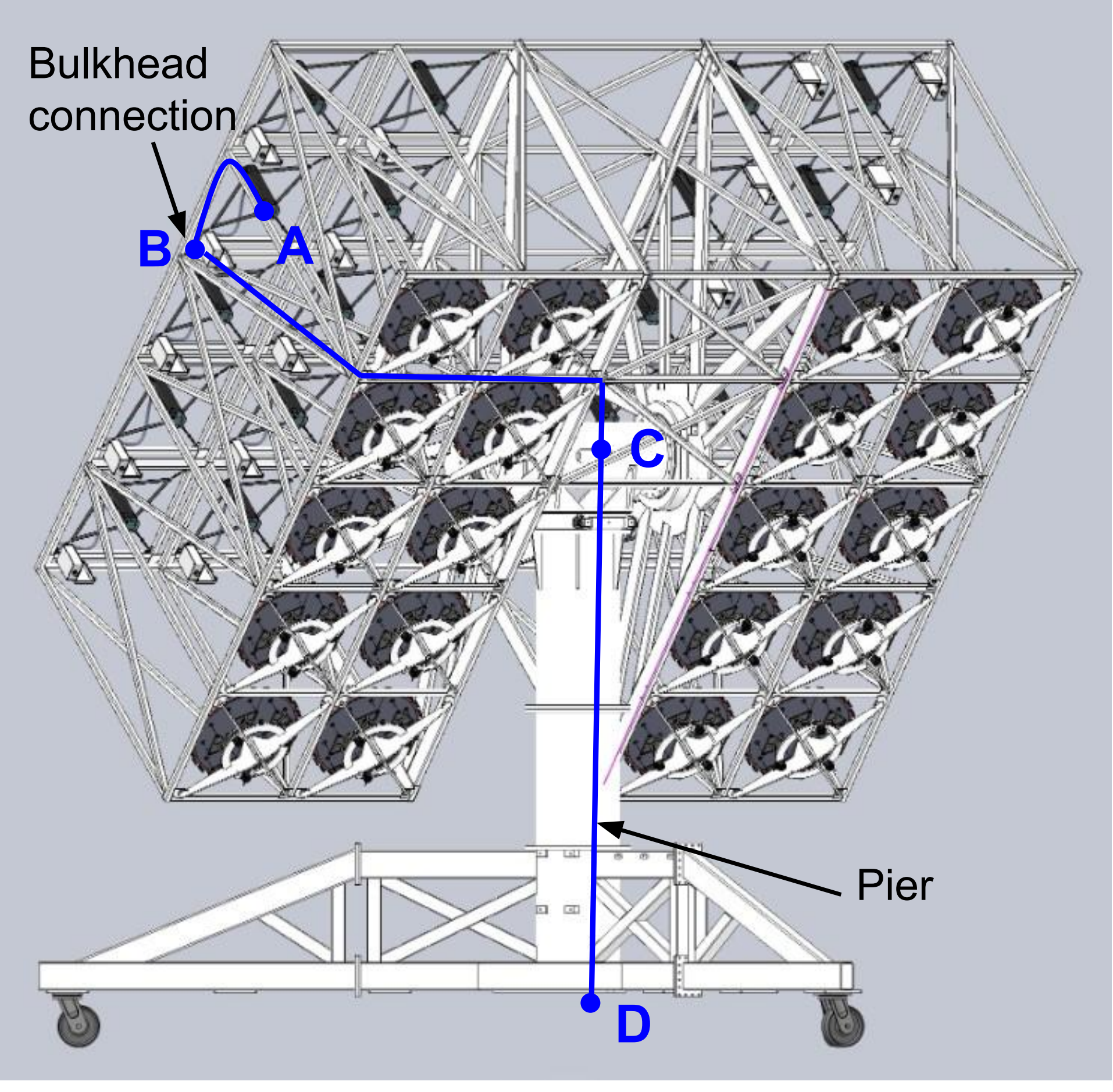


Fig. 1 LFAST telescope mount with 20 unit telescopes each feeding into an optical fiber. Blue line shows the routing of one fiber on the mount. The other 19 route similarly.

LFAST & OPTICAL FIBERS

Step-index multimode fused silica fibers collect light from the primary at the prime focus (Fig. 2) of each telescope, and transmit it to the entrance slit of the spectrograph.

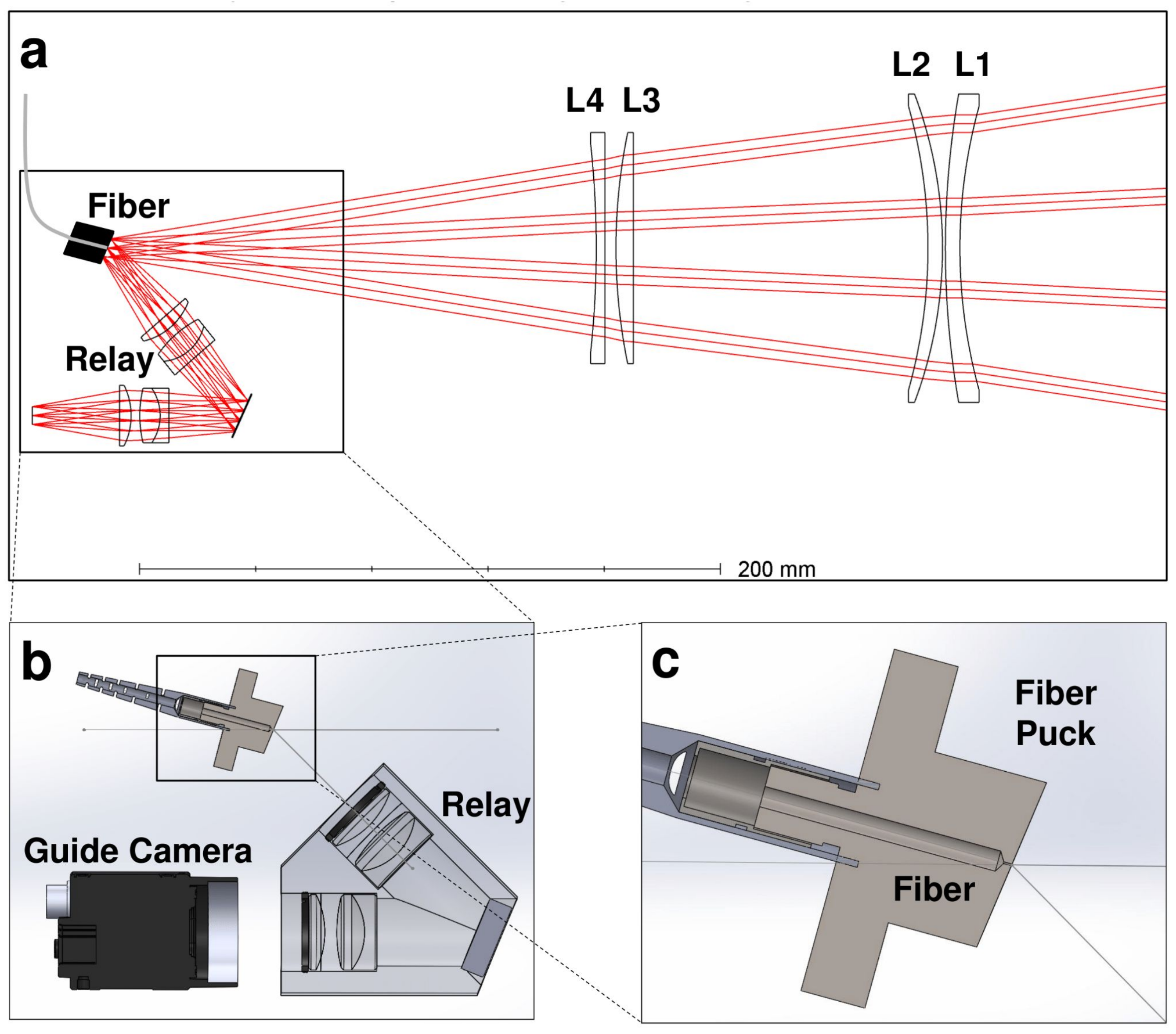
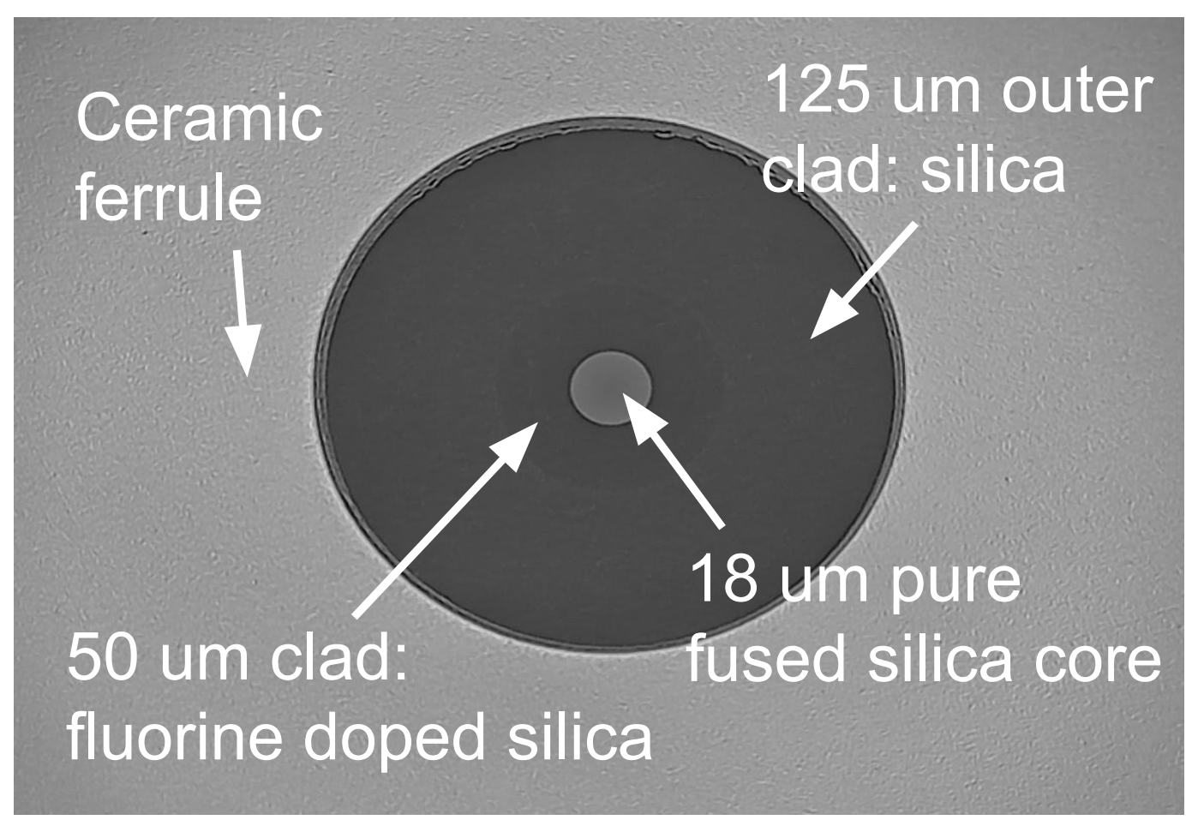


Fig. 2 (a) Telescope top-end optical layout (Berkson et al. 2024), (b) zoomed in relay optics, (c) fiber puck

The fiber-feed design has the following requirements:
1. maximizing light throughput from 400nm - 1800nm
2. minimizing the increase in etendue (e.g., FRD)
3. maintaining buildability for low-cost mass production



The LFAST 0.76m primary mirror operates at f/3.5. We plan for a 1" site, and design for a fiber that subtends 1.4", corresponding to an 18um fiber core. This core size places our optical fiber in the **'few mode' regime**, significantly smaller than the typical core size used in astronomy. We have procured a custom fiber draw from CeramOptec to test fiber performance.

LFAST Prototype Fiber Characteristics	
Low OH WFNS, NA=0.22	NA is well-matched to f/3.5 telescopes.
18 um core, 50 um clad, 125 um outer clad	Outer clad facilitates standard, off-the-shelf ceramic ferrules and connectors.
Polyimide buffer, FC/PC connectors	Stripped with H_2SO_4 and epoxied with Epotek 301-2 for low stress

FIBER FEED DESIGN

To facilitate mass production, installation, and repair, the receiving fiber segments are connected by bulkheads. Fig. 1 shows the path of a fiber coming out of a unit telescope:

- The first 2 m segment is potted into the stainless steel puck (A) in the prime focus unit and connects to bulkhead (B) in the electronics box.
- The second 11 m segment runs along the back frame and joins the other fibers at (C), and ends at the junction box at the base of the pier (D).

We are exploring the use of index matching gel to reduce losses at bulkheads.

PUCK COATING & ABLATION

The 304 stainless steel fiber puck reflects light from an 8' field for guiding (Fig. 2c). The small size of our primary mirror limits light available to the guider, and the low reflectivity of stainless steel will limit the guiding performance. Coating the puck with aluminium dramatically increases surface reflectivity. We simulated density of guider stars with realistic system throughput: there is a 100% chance of a R<16 star falling into this FOV.

We coat the fiber puck with aluminium using a Cressington 308 evaporative coating chamber (Fig. 5) in the University of Arizona fiber lab.

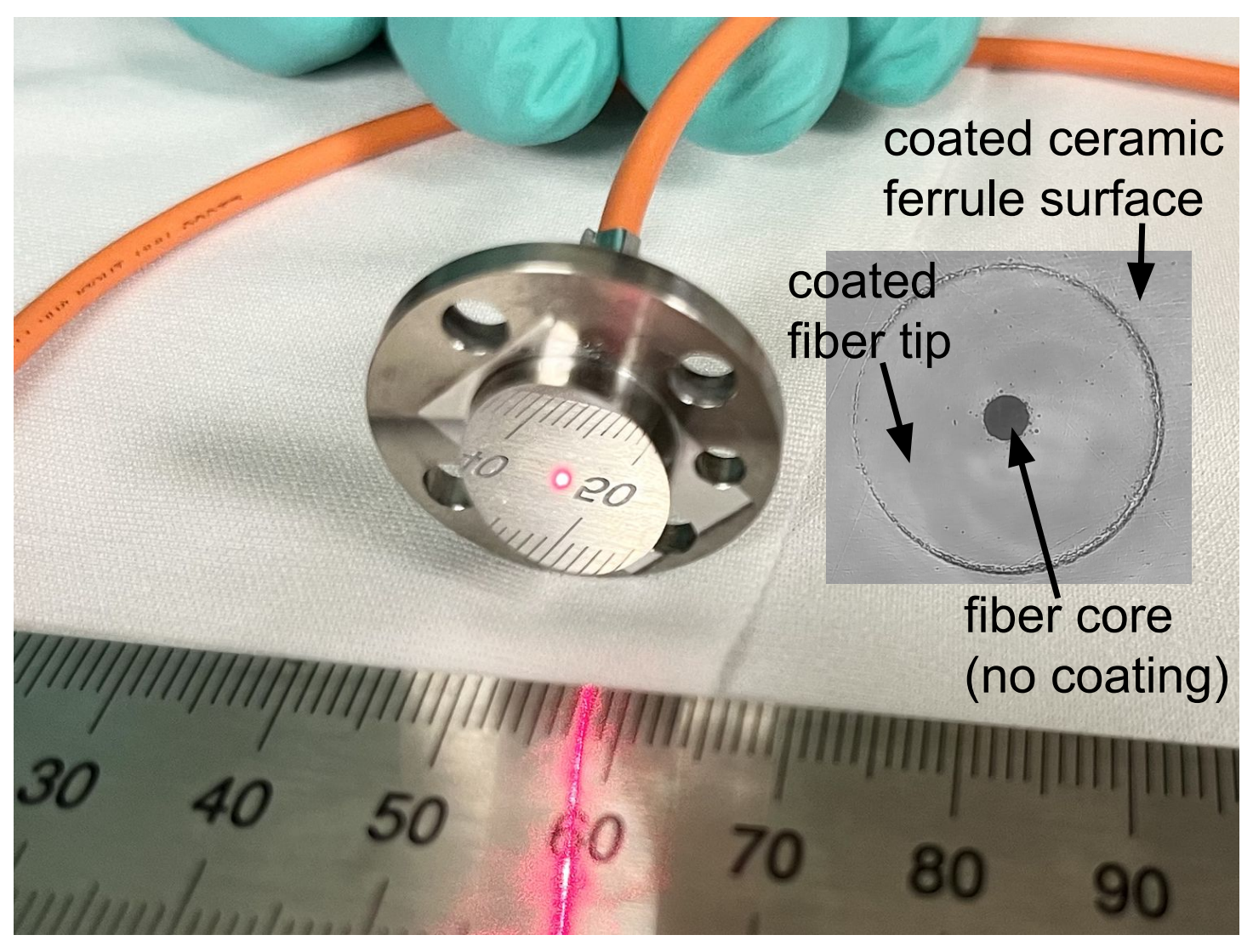


Fig. 4 Al coated and ablated fiber puck, illuminated by red laser. Inset shows another coated fiber and ferrule processed identically to the puck; ring structure is the epoxy layer.

To prevent aluminium from depositing on the fiber surface, we ablate the metal by back illuminating the fiber with a 1064 nm picosecond pulsed laser (Thorlabs QSL106B) at 150 mW average power (1.7uJ pulse) during the coating process.

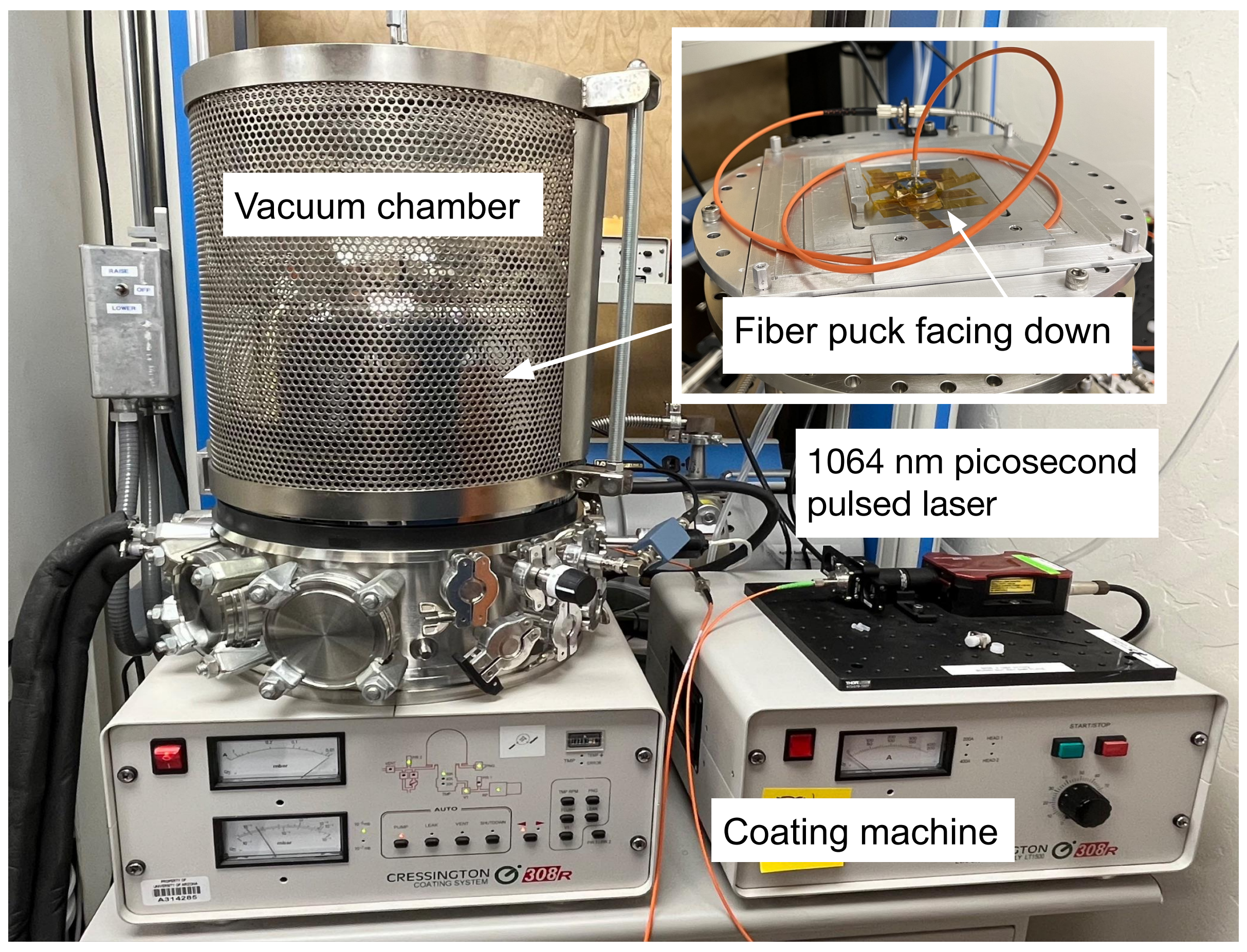


Fig. 5 Fiber coating chamber set-up. The fiber inside the coating chamber is connected to the laser through a delivery fiber which passes through the vacuum flange.

Fiber Characterization

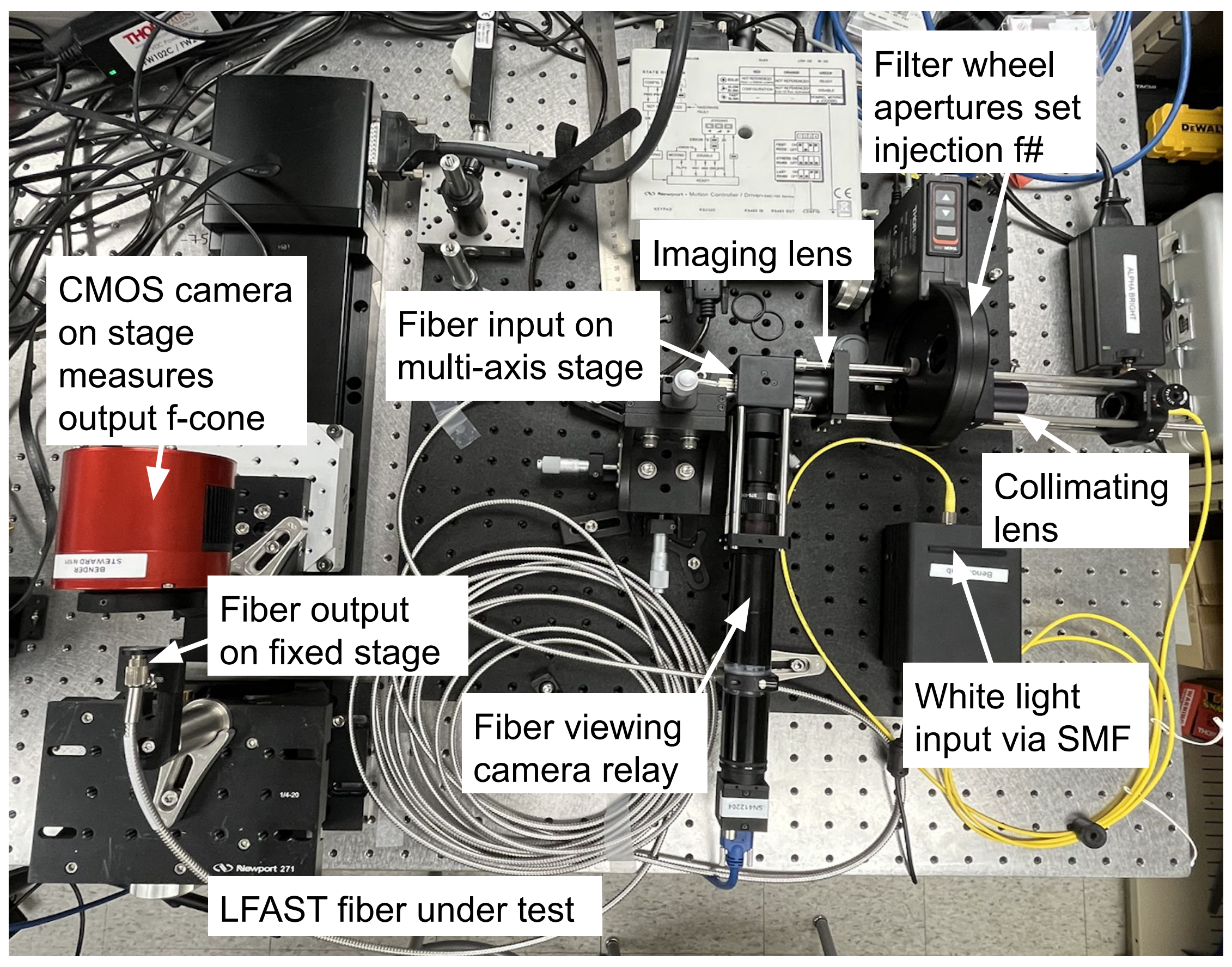
1. Fiber surface flatness:

Since we are using bulkhead connections throughout the telescope, surface flatness is crucial to fiber coupling, and hence the optical performance of LFAST. Measurements with a FIBO Interferometer indicate that we can achieve sub-arcsec surface angle and ~100 nm flatness in the UofA fiber lab.

Polished fibers surface performance		
Fiber serial number	Surface angle	Peak-to-Valley
LFAST-P-CWFNS18P22-0011 (Face 1)	0.055°	124.7 nm
LFAST-P-CWFNS18P22-0011 (Face 2)	0.001°	69.9 nm
LFAST-P-CWFNS18P22-0014 (Face 1)	0.012°	117.3 nm
LFAST-P-CWFNS18P22-0014 (Face 2)	0.004°	47.5 nm

2. Focal ratio degradation (FRD):

LFAST telescopes illuminate the fibers with an f/3.5 beam. To design the spectrograph, we need to measure the fiber output f/#. Stress from fiber-end termination, e.g. crimping/ epoxy, is a common cause of FRD. Studying the FRD performance of LFAST fibers helps improve our fabrication procedures.



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This project is supported by Schmidt Sciences, LLC.