Modifying Hydra for the WIYN telescope – an optimum telescope, fiber MOS combination

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ABSTRACT

The KPNO fiber-fed, multi-object spectroscopic instrument, Hydra, is being moved from the Mayall to the WIYN telescope. The WIYN telescope has good concentricity between the focal surface radius and the exit pupil. The primary modification to the instrument will allow the fibers to align with the telescope exit pupil while lying along the curved focal surface. Maximum pupil alignment losses will be reduced from 15% at the Mayall to 5% at the WIYN. The new orientation of the instrument requires a different mechanism for accessing the fiber and focal plate for maintenance. We are also upgrading the manner in which the fibers are held in place around the focal plane in order to reduce neighboring fiber interactions beyond the pivot circle. The wavelength calibration assembly is being modified to take advantage of extra room in the instrument. For guiding, instead of using offset guide probes, we are developing an algorithm which will utilize the field orientation probes. The Bench Spectrograph associated with Hydra is also being moved over to the WIYN, however, we do not discuss the spectrograph in this paper.

1. INTRODUCTION

Hydra, a multi-object fiber positioner and spectrograph first constructed for the Mayall 4 meter telescope,[1,2] is being reconfigured for permanent installation on the WIYN 3.5 meter telescope.[3] Several important differences between the Mayall and WIYN telescopes require modification to the instrument. First, the vertical orientation of the instrument on WIYN requires a different mechanism for physical access to the focal plane than is used in Hydra's horizontal position on the Mayall. Second, the better match between the exit pupil distance and focal surface radius of curvature on the WIYN leads to the desire to place the fibers on a spherical focal plate as opposed to a flat, stepped plate as at the Mayall. These are the two leading reasons for radical modification of the current instrument.

Other changes to Hydra are being made to enhance its reliability and performance. Among these are an improvement in the fiber pivot arrangement to reduce neighboring fiber interactions beyond the pivot circle and to minimize stress on the fiber as it is transported; an increase in the number of available fiber locations from 200 to 288 to accommodate future cables; improvement in the gripper design to provide better grip adjustment; and a better scheme for managing the fibers beneath the focal plate.

Since Hydra will effectively be the only instrument installed on the wide field MOS Nasmyth location, aspects of guiding and calibration became the responsibility of the instrument. We are moving the wavelength calibration lamps and illuminating screen into the spacer assembly which connects the positioner to the instrument rotator. Instead of typical offset guide probes, guiding will use the field orientation probes which are positioned on the focal plate in the same manner as and along with the science fibers.

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2. FOCAL PLANE CHARACTERISTICS

Proper alignment of a fiber with both the focal plane and the exit pupil is crucial for maximizing the throughput of the fibers.[4,5,6] The Mayall telescope has an RC focus with a 3.3 meter radius of curvature. The exit pupil lies approximately 12.7 meters from the focal surface. Given this case, Hydra was designed with a flat, but stepped focal plate in order to approximate the curved field while keeping the fibers in approximate alignment with the exit pupil. The pupil alignment error at the edge of the field is on the order of 0.9°[7] which can correspond to a 15% loss of light if the spectrograph collimator had the same focal ratio as the f/8 telescope. The actual pupil alignment losses should be somewhat less since the actual collimator used has a focal ratio of f/6.7 to accommodate the fiber focal ratio degradation (FRD). If the focal plate had been curved to match the field, the pupil misalignment would have been as large as 2.5°!

The WIYN telescope is designed for optimal fiber optic coupling. The f/6.3 focal ratio was selected to fall within an optimal range of minimal FRD and adequate image scrambling.[8,9] Efforts in the design were also made to ensure that the exit pupil distance matched the focal surface radius of curvature within an acceptable tolerance. The resultant exit pupil lies approximately 6.9 meters from the focal plane while the radius of curvature is about 5.7 meters. The chief rays at the edge of the 1 degree diameter field are deviated by only 20 arc-minutes from the normal to the focal surface.

To take the fullest advantage of this effort in making the WIYN a "concentric" telescope (ie. the radius of curvature of the focal surface is concentric with the distance to the exit pupil), we desire to place the fibers onto a spherical focal plate with a radius that places the fibers onto the true focal surface.

We tested the ability of the current gripper to place fibers onto a 2° tilted surface (equal to the tilt at the edge of the desired spherical focal plate) without any tip-tilt in the gripper. The placement precision degraded by a factor of 2 to 3 compared with fiber placement onto a non-tilted surface. This left us with the options to implement either a complex tip-tilt gripper mechanism or to warp a flat focal plate to the desired shape after the fibers were positioned. A tip-tilt mechanism would have introduced 2 more axes of motion to the fiber positioner requiring extensive development and software efforts. On the other hand, the warped plate concept allowed the positioner to remain as is with the complexity being increased only by the mechanism to warp the plate. We opted to pursue the warpable plate.

Plate warping has been used in fiber plugboard schemes by mechanically pulling on the center of the plate[10] or by warping with clamps around the plate's edge.[5] In our case, we can utilize a vacuum to warp the plate since our fibers reside completely on the plate's forward face. A properly shaped backstop defines the plate's deflection and shape. Figure 1 shows a schematic view of the focal plate in its flat and warped positions. The fibers are positioned while the plate is flat. Warping the plate then aligns the fibers with the exit pupil and places the fiber ends along the focal surface. Measurements of radii along the warped focal plate show that the depth of the plate matches that of the desired sphere to better than 0.001 inches and that the tilt of the plane aligns with the exit pupil to a maximum error of less than 0.4°. The typical depth and tilt errors of the warped plate, as a function of field radius, are shown in Figure 2. For a matched collimator, the pupil alignment losses should be less than 5.6%.

The 15 inch diameter focal plate is fabricated from one-eighth inch thick 410 stainless steel. A black oxide coating is added to reduce scattered light reflections from bright stars.

3. FIBER MANAGEMENT

Another area of instrument improvement concerns the fiber mounting and management near the focal plate. The current pivot blocks are being replaced by long grooved channels to prevent entangling of neighboring fibers outside of the pivot circle and to lessen any stress on the fiber when it is being transported by the gripper. The pivot blocks and focal plate are shown in Figure 3. In order to minimize crowding effects of neighboring fibers on the target assignment, the park level of the fibers is lowered so that the hypodermic tube of an assigned fiber can pass over neighboring parked fibers. This is shown in Figure 4.

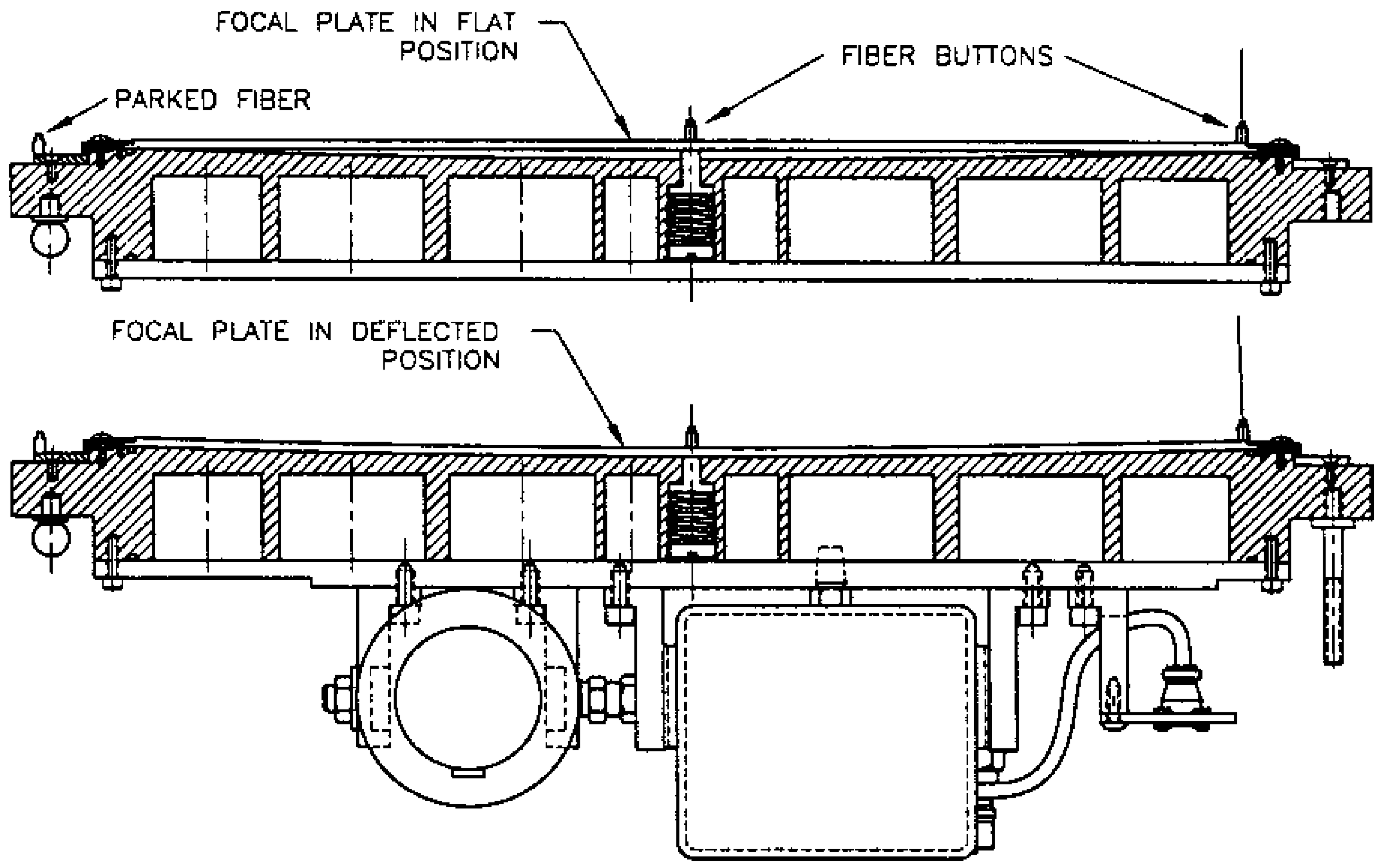

Figure 1: The warpable plate and fibers in both the flat and warped positions.

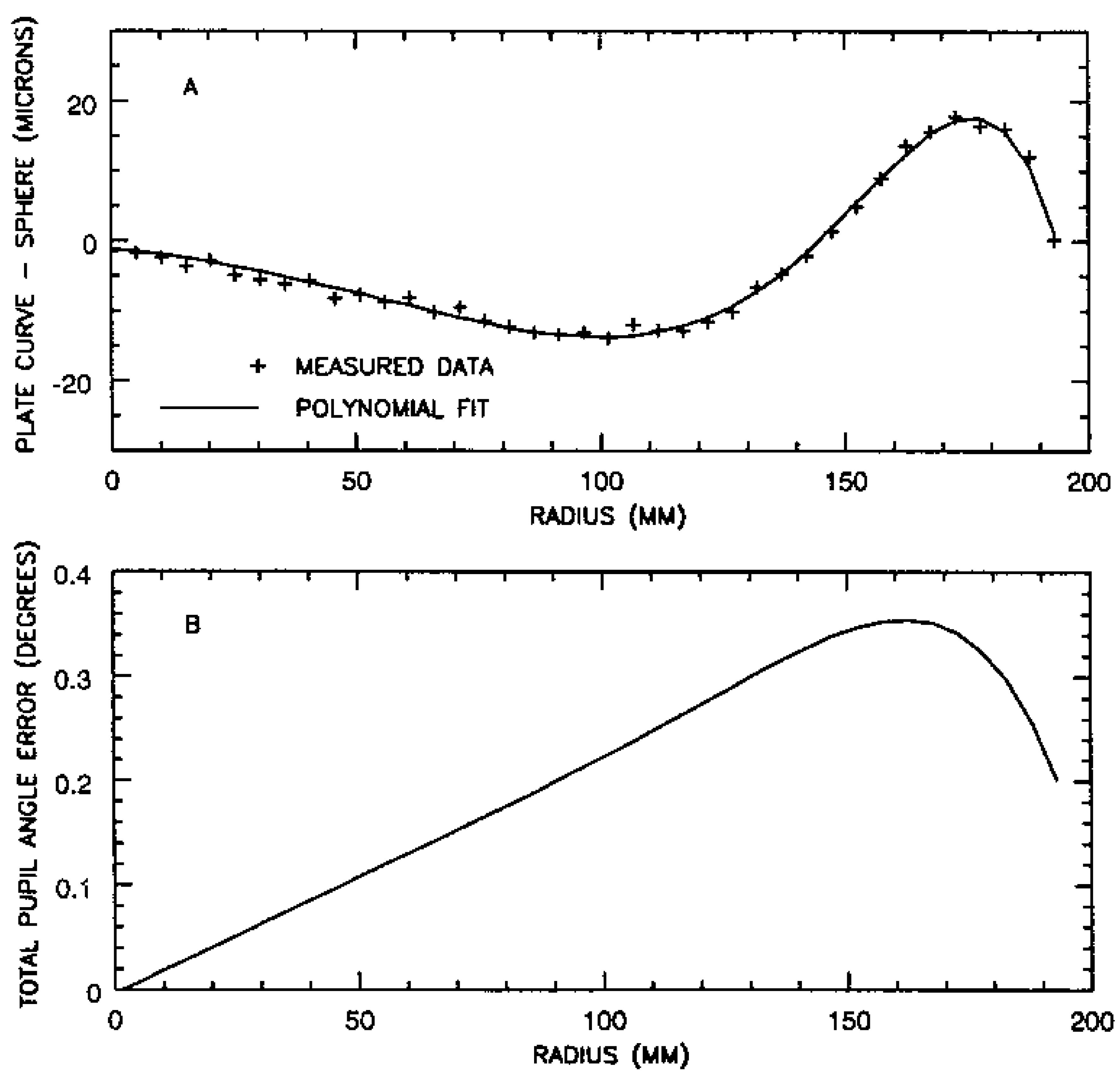

Figure 2: A: Depth difference between the warped focal plate and the desired spherical surface. B: The angle between the chief ray and a line normal to the warped plate.

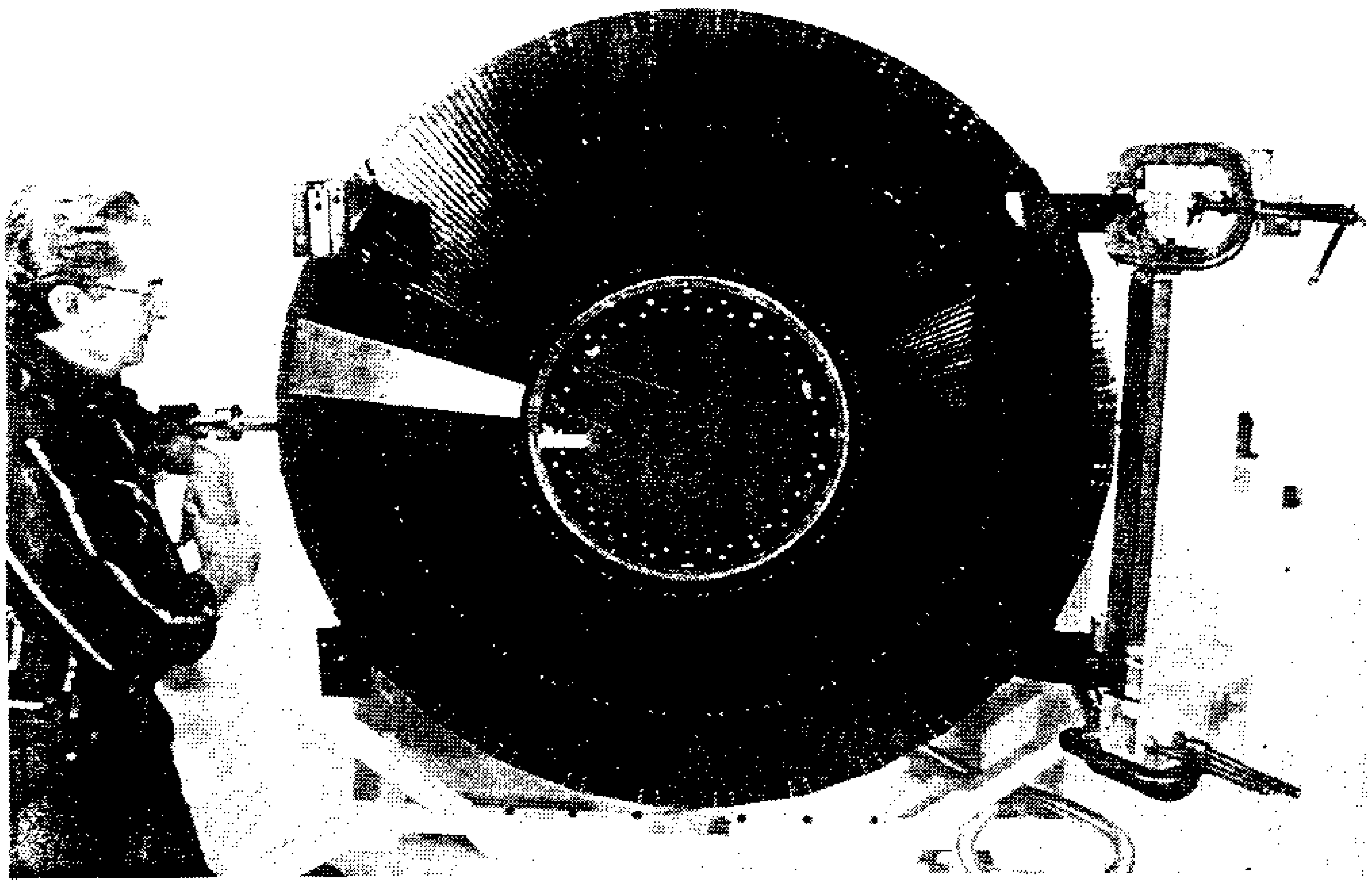

Figure 3: Pivot blocks surrounding the focal plate. Some test fibers are shown extending from the blocks onto the plate.

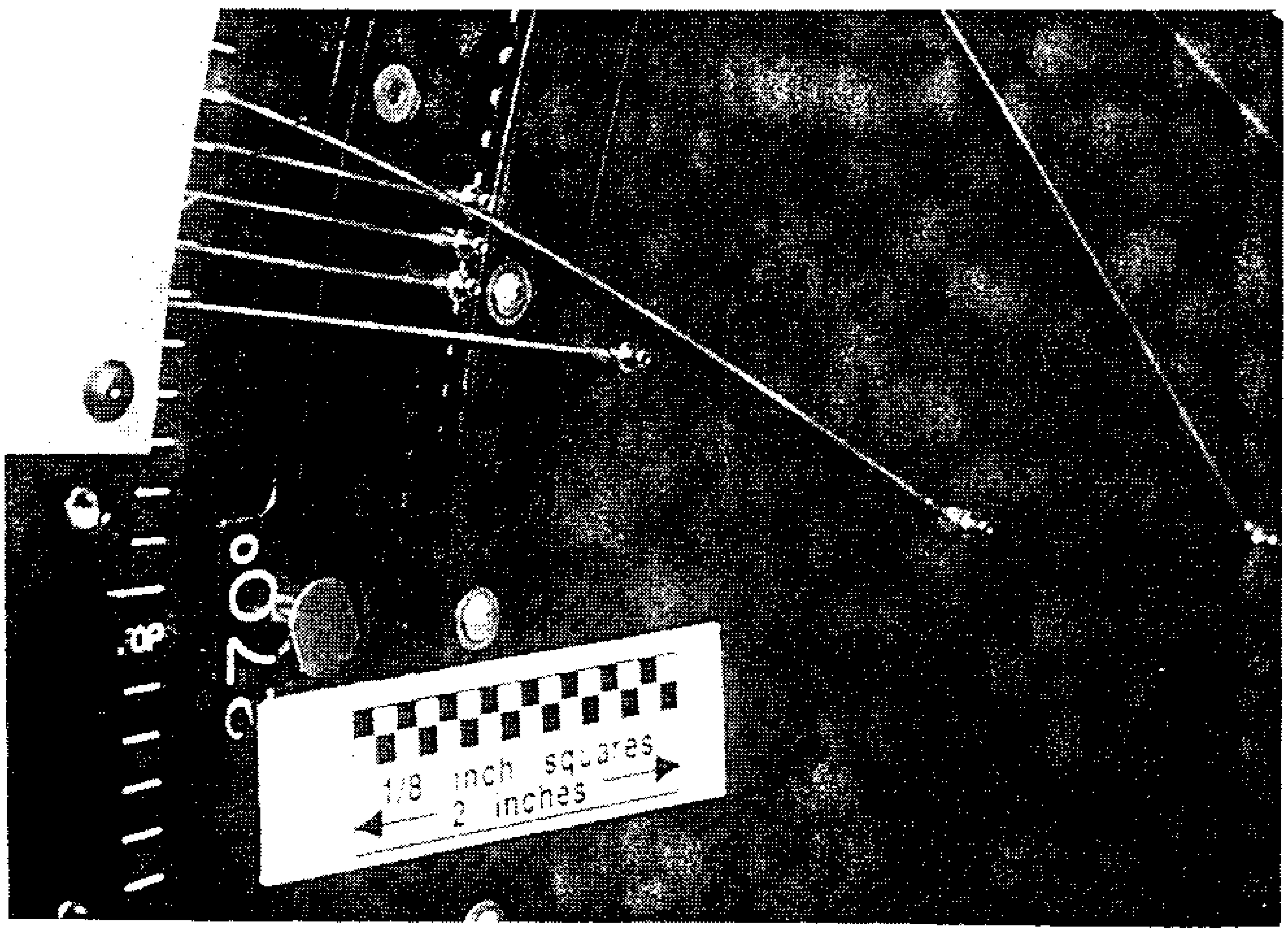

Figure 4: Detailed view of how fibers can be placed over neighboring fibers which are parked.

The fibers are sheathed in the same manner as those used at the 4 meter. The first 16 inches from the fiber button are mounted in a thin, hypodermic tube. Beyond that tube, the fiber is protected by a teflon tube for the remaining 25 meter length to the spectrograph. Along the backside of the focal plate assembly, the fibers are grouped, bundled together, and clamped in an orderly fashion. A flexible, metal hose encases the fibers from the focal plate assembly to the spectrograph. Figure 5 shows a cutaway, side view of the fiber management scheme.

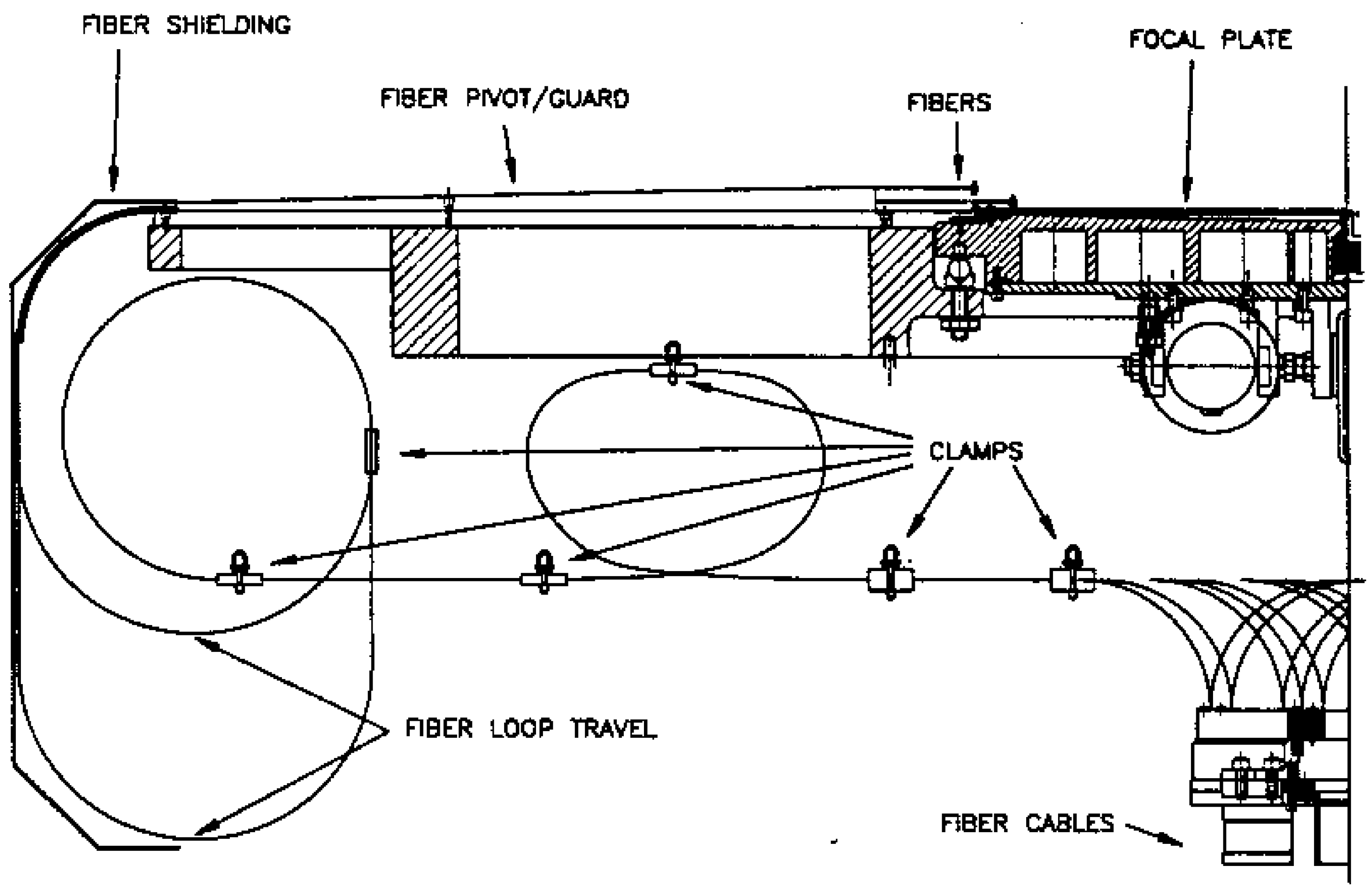

Figure 5: Side View of the fiber management.

4. CALIBRATION MECHANISM

For maximum observing efficiency, calibration sources should illuminate the full 1 degree field of view. This eliminates the need and time to reposition the fibers for calibrations. Both flat fielding and wavelength calibrations are desired during the course of the night.

Flat fielding will be carried out by pointing the telescope at a large white spot on the side of the dome. Quartz lamps mounted on the telescope will illuminate this spot. This is the same technique as that used at the Mayall.

Wavelength calibration will be done via lamps, mirrors, and a screen mounted within the instrument mounting adapter. Hollow cathode tubes are used for both high dispersion (Th-Ar lamps) and low dispersion (Cu-Ar lamps) observations. Since such tubes tend to be faint and because we desire to have good uniform illumination over the entire 1 degree field, eight lamps of each type (16 total lamps) will be used to illuminate the screen. Switching between Th-Ar and Cu-Ar will be a fairly quick and easy process.

Figure 6 shows the illumination layout for a single lamp. Each lamp produces an uneven elliptical illumination patch on the screen over an area roughly equal to half the screen area. With eight lamps, the uniformity of illumination is expected to be within a factor of 1.5 across the field.

The screen is made up of 8 pie-shaped wedges which fold out of the optical path when not in use. We selected a material called spectralon (from labshpere, Inc.) for the screen because it has a very diffuse reflectivity with high efficiency across the optical spectrum.

5. GRIPPER ENHANCEMENTS

The current Hydra gripper[1,2] works very well. However, adjustment of the gripper is difficult, especially for the "relaxed grip" which allows the fiber buttons to rotate as they are transported. We are upgrading the gripper to

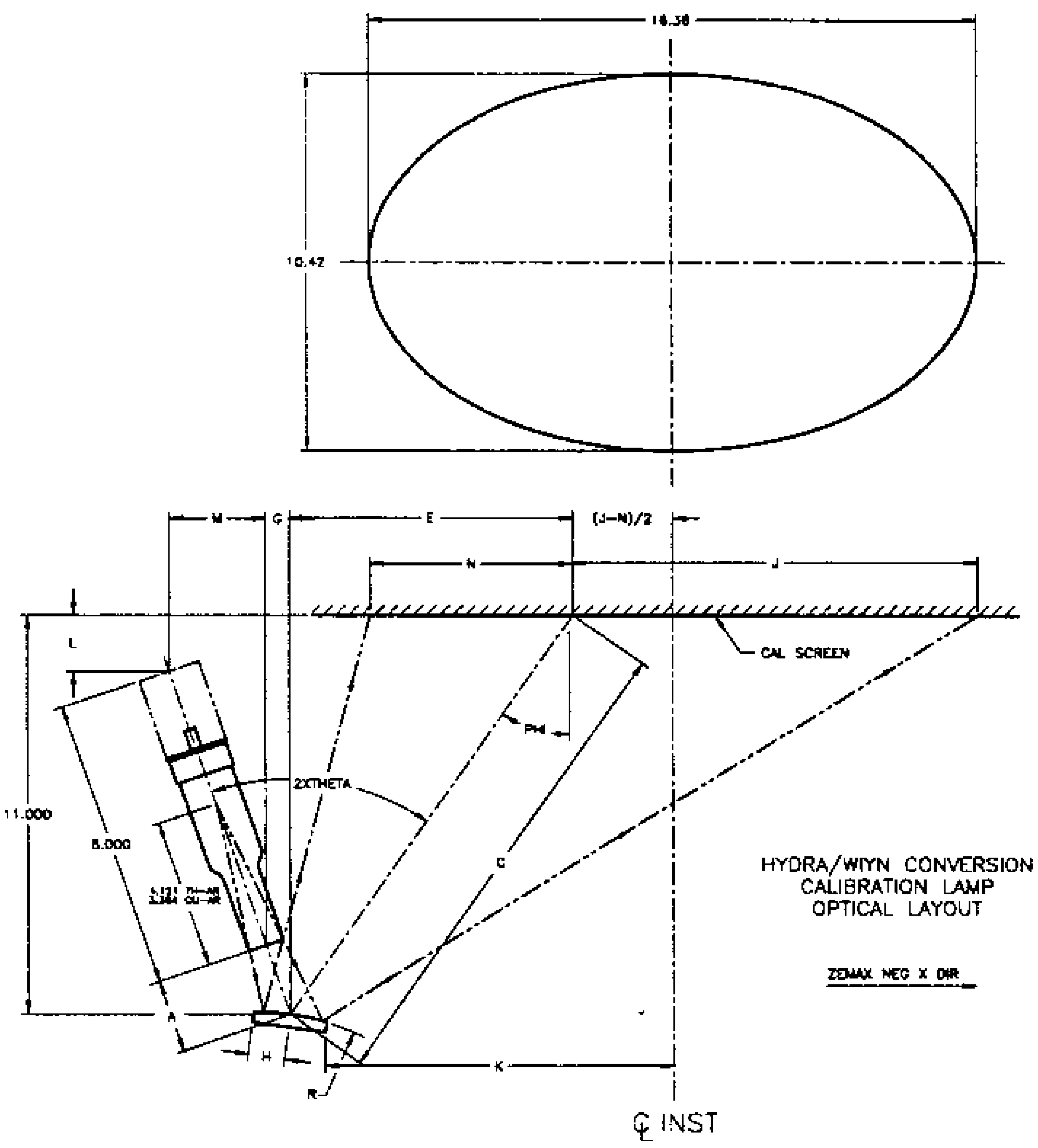

Figure 6: Schematic of the wavelength calibration illumination scheme. Only one of eight total lamps are shown. The characteristic beam shape is shown at the top by the ellipse.

provide better adjustment of this gripping force. Figure 7 shows the comparison of the gripping forces between the current and new design as a function of the gripper actuator travel. Overplotted is the diameter of the gripper jaws which becomes a constant equal to the button diameter when a button is in the gripper (as shown).

A schematic of the new gripper design is shown in Figure 8.

6. HYDRA ASSEMBLY

Figure 9 shows a cutaway, side view of the full instrument. The bank of hollow cathode tubes are shown in the spacer assembly as well as some of the screen wedges. The screen pieces are folded out of the beam in this illustration. For calibration exposures, the eight wedges are positioned to form a circular screen at the spacer/rotator interface.

7. FOCAL PLANE ACCESS

Access to the focal plane and fibers at the Mayall was done by releasing four clamps and lowering the focal plate assembly down on some rails. Negator springs enabled the assembly to be easily lifted back to the positioner for reassembly. This mechanism obviously would not work at WIYN where the instrument is mounted vertically.

A hinge coupling was developed for access at the WIYN. Figure 10 shows the same cutaway, side view of Hydra as in Figure 9 but with the hinge in its open position.

Due to the weight of the instrument, it should only be opened at a specific rotational orientation. To prevent opening the instrument at any unsafe orientation, the lockout mechanism shown in Figure 11 was developed. The

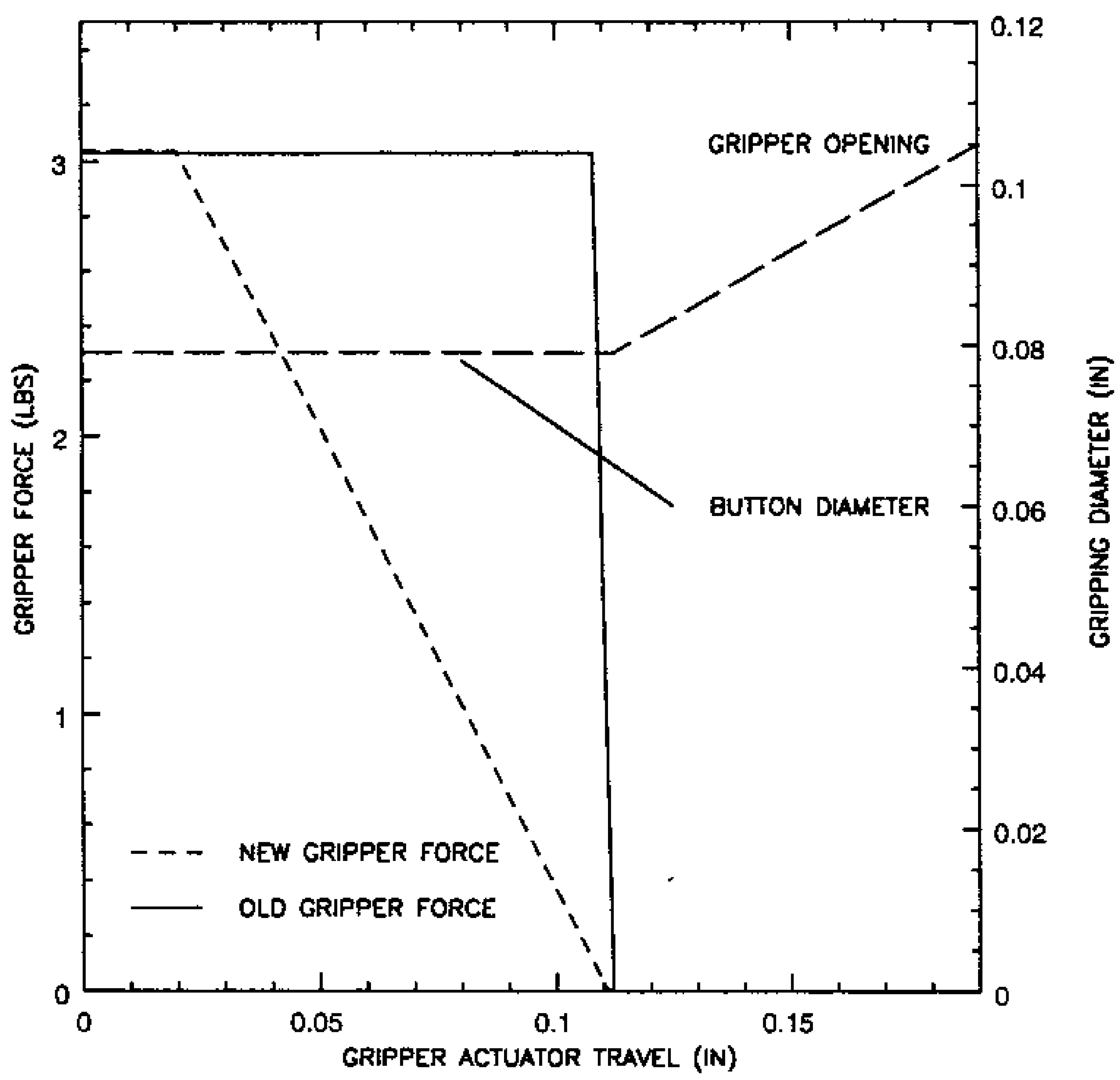

Figure 7: Gripping force for the old and new gripper designs. The diameter of the gripper jaws is shown to indicate where the gripper releases a fiber button.

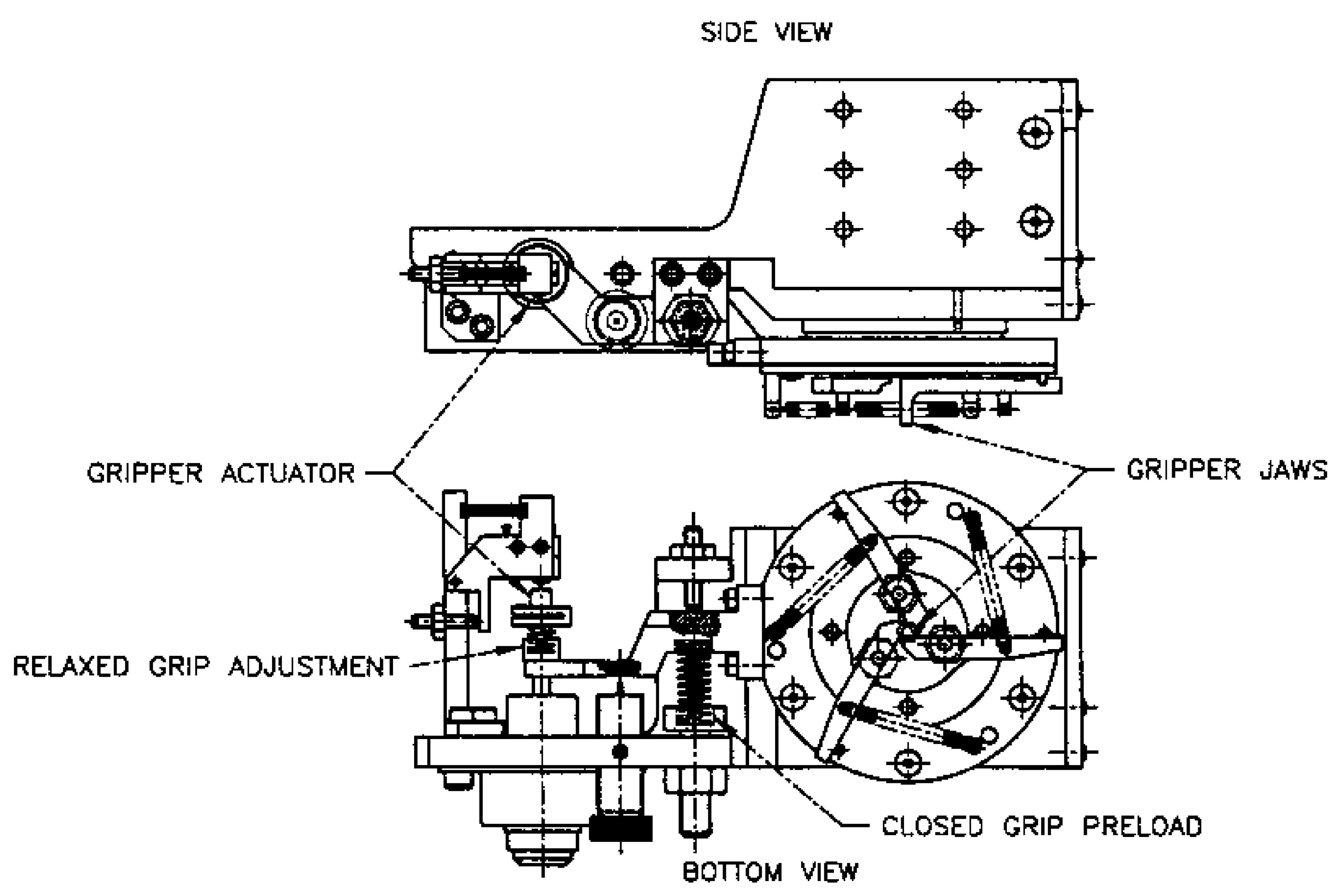

Figure 8: Schematic drawing of the new gripper.

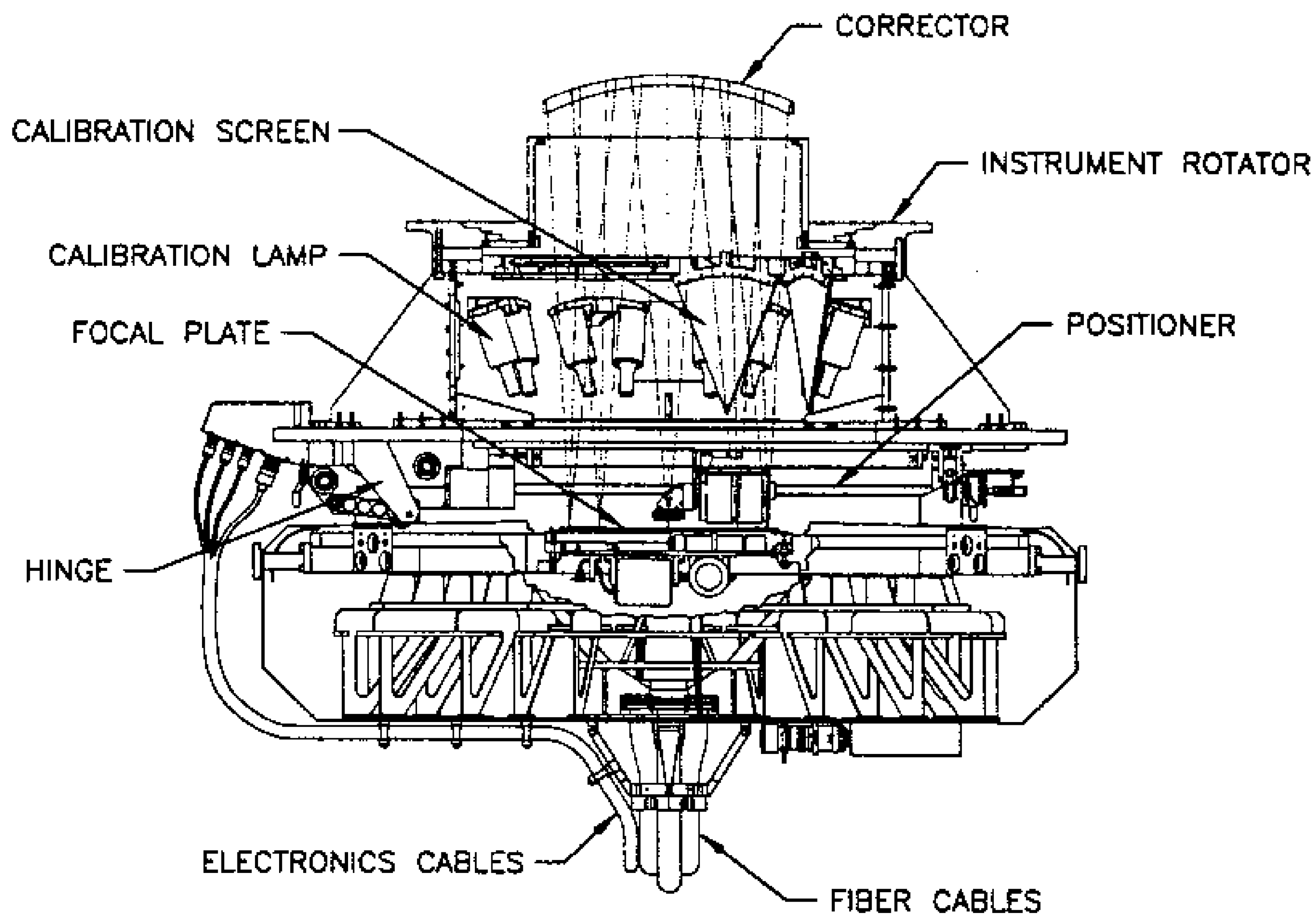

Figure 9: Cutaway side view of Hydra on the Nasmyth platform.

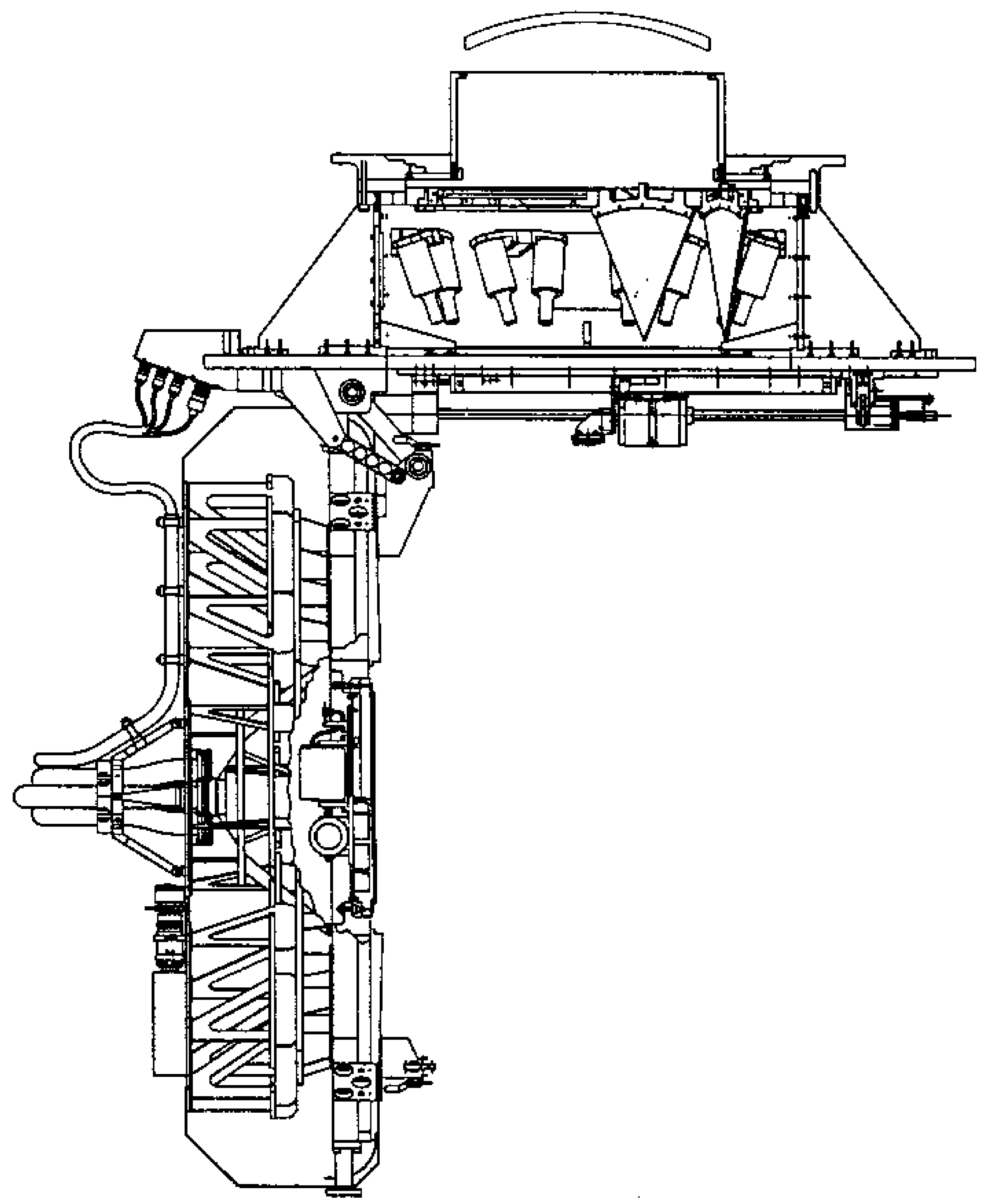

Figure 10: Cutaway view of Hydra with the hinge in the open position.

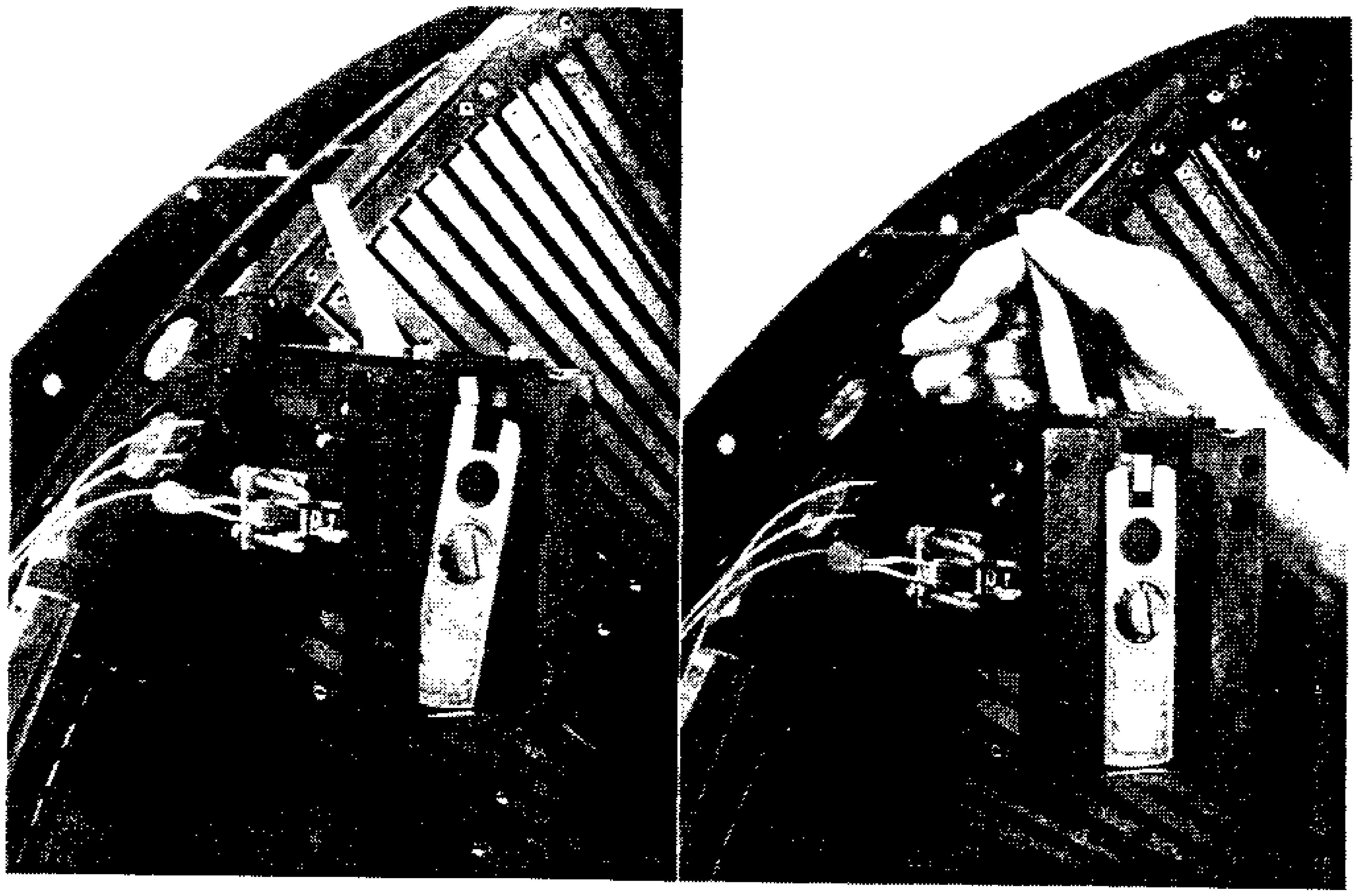

Figure 11: Hinge lockout mechanism. Left shows the lockout when the gravity vector is incorrect. Right shows proper alignment of the gravity vector with the instrument for unlocking the hinge.

pendulum tilts and locks out the ability to open the hinge when the gravity vector is not properly aligned with the instrument.

8. HYDRA GUIDER

For automated guiding of the telescope, we will utilize probes each consisting of a bundle of 7 hexagonally packed fibers. The probes are placed on target stars in the same manner as the science fibers. These same type of probes have been used on Nessie[7] and on Hydra at the Mayall telescope.[2] We call them field orientation probes (FOP) since they are used to align and lock onto the field being observed. A schematic representation of a FOP is shown in Figure 12. There will be a total of twelve FOPs equally spaced around the focal plate.

We have run some initial simulations of a basic centroiding algorithm. The algorithm, which computes the first moment of the signal coming through the seven fibers, produces a centroid with fairly good accuracy given that the seeing is neither too good nor too bad. Figure 13 shows the computed centroid versus the actual position of a simulated star on a simulated FOP. The proposed FOPs should work quite well when the image FWHM is somewhere between 1 and 3 arc-seconds. Although we may need to implement a complement of FOPs consisting of smaller fibers in order to achieve better performance when the seeing FWHM is sub-arc-second, losses in the 2 arc-second science fibers are somewhat less dependent on image displacement in such cases so that the current FOPs may actually suffice.

9. PROJECT SCHEDULE

Hardware for the focal plate assembly is nearly completed. Design and fabrication of the spacer and calibration assembly are underway. Hydra is scheduled for decommissioning from the Mayall in early July, 1994. Final renova-

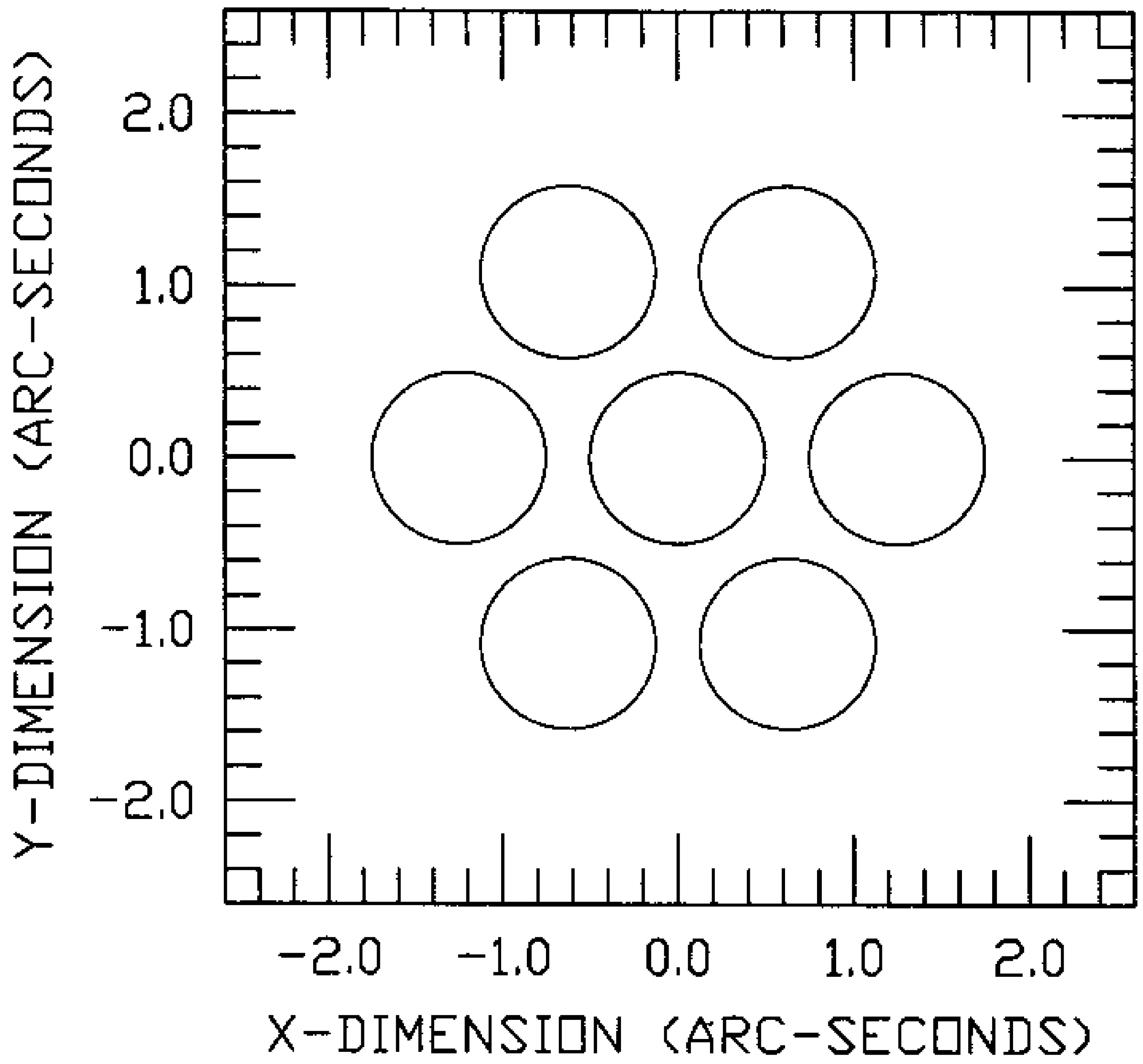

Figure 12: Schematic layout of the fibers in a single field orientation probe (FOP).

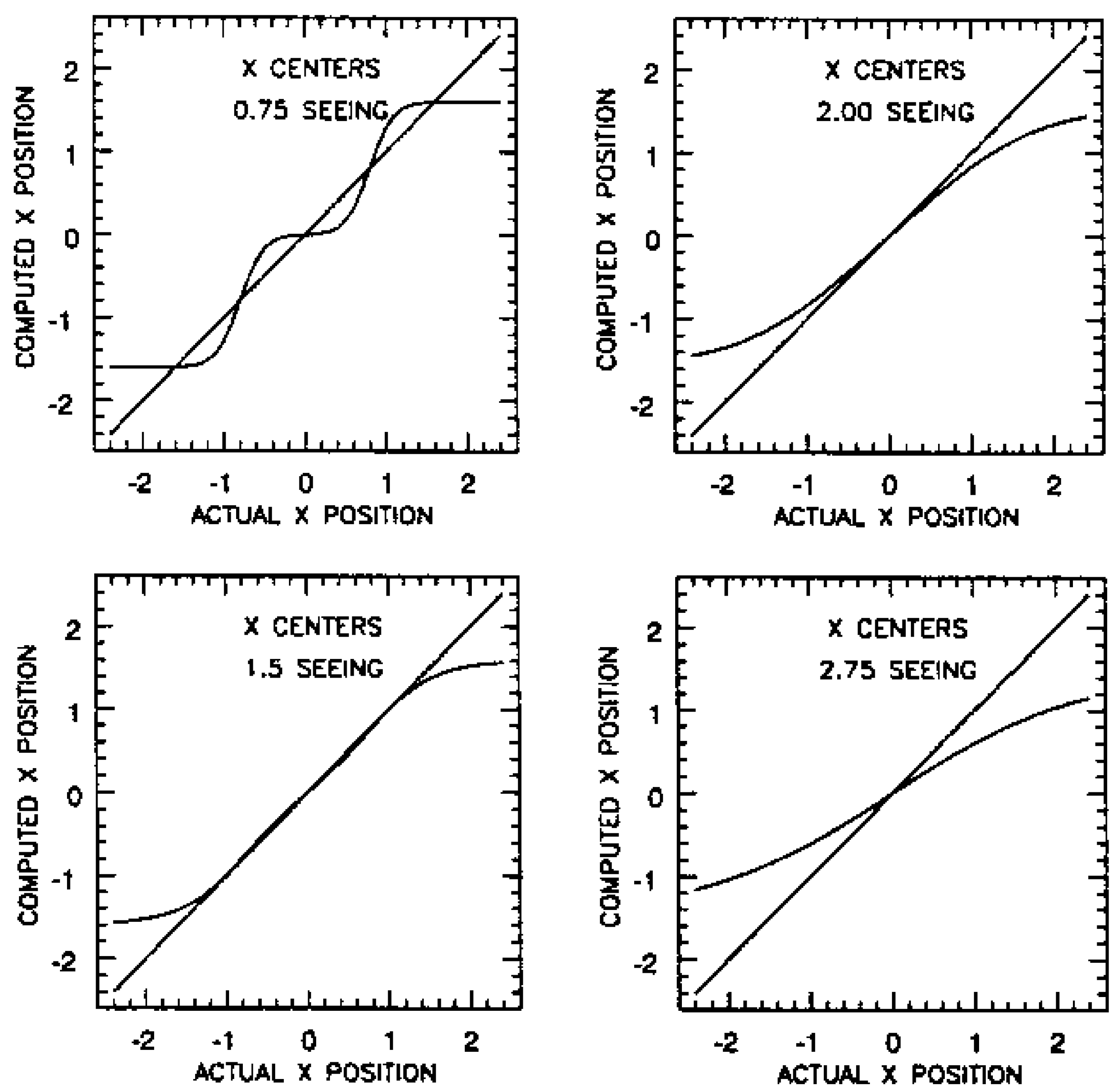

Figure 13: Computed centroid versus actual position of a simulated star shifted along the X-axis of the FOP for a variety of seeing conditions.

tions will take place during the summer with commissioning on WIYN starting in the fall. Shared risk, scientific use should start in early 1995.

10. ACKNOWLEDGMENTS

The authors of this paper make up a small part of the team involved in the efforts to design and modify Hydra for the WIYN telescope. The optical design of the telescope was accomplished by Charles Harmer. His efforts to keep the telescope optimized for fiber use are greatly appreciated. Designers and detailers for modifying Hydra include Ron McLean, Rich Gomez, and Eddie Salinas. Instrument making efforts are provided by Jim Irvine, John Stein, Jeff Gibson, Dwayne Miller, and Larry Junco. Engineering of the Bench Spectrograph is headed by David Vaughnn.

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The warpable plate concept arose during a conversation between S. Barden and Paul Harding. Paul's suggestions are appreciated.

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