HYDRA/WIYN USERS MANUAL - DRAFT v2

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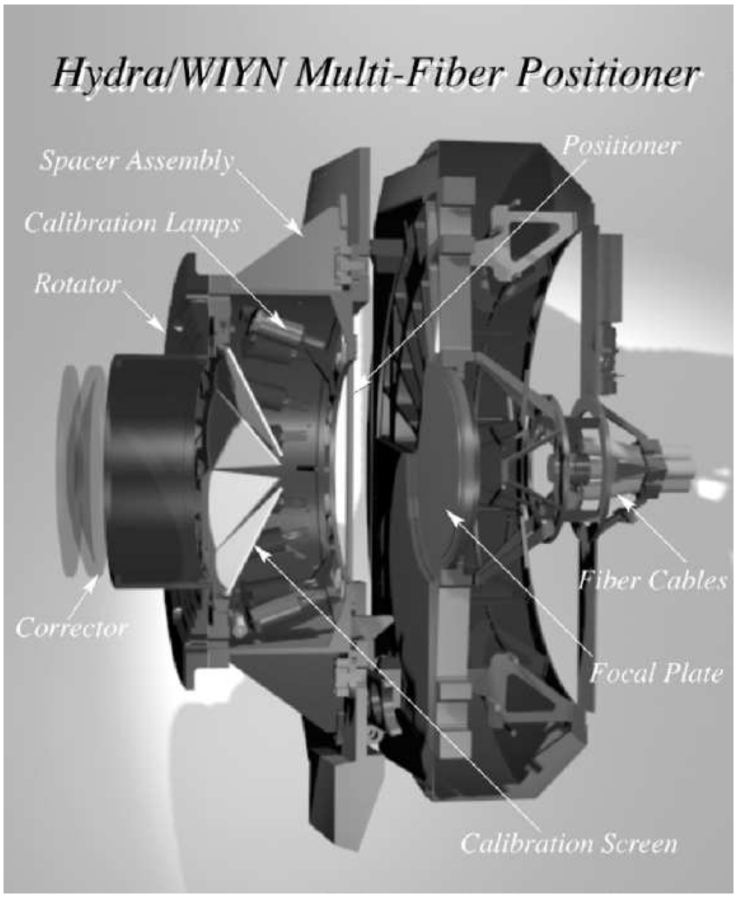

Abstract

Hydra is a fiber positioner on the WIYN 3.5 meter telescope for multi-object spectroscopy of up to 100 objects over a 1 degree field. An optimized, bench mounted spectrograph provides low, moderate, or high dispersion spectra.

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Part I
STAFF CONTACTS AND INTRODUCTION

1 STAFF CONTACTS

The following staff are available for questions related to Hydra observing.

- For NOAO queue observing assistance, you should contact:

  Di Harmer – (520)318-8218 – dharmer@noao.edu

  Dave Silva – (520)318-8358 – dsilva@noao.edu

  Daryl Willmarth – (520)318-8333 – willmart@noao.edu

- The following staff are in charge of university instrument starts and setups:

  Jim De Veny – (520)318-8390 – jdeveny@noao.edu

  Daryl Willmarth – (520)318-8333 – willmart@noao.edu

  Dave Sawyer – (520)318-8570 – dsawyer@noao.edu

- For general information about the Hydra instrument, please feel free to contact:

  Sam Barden – (520)318-8263 – barden@noao.edu

  Taft Armandroff – (520)318-8382 – armand@noao.edu

- For assistance on astrometry and target assignments, you may try the services of:

  Phil Massey – (520)318-8271 – massey@noao.edu

2 INTRODUCTION

Hydra derived its name from the resemblance of the fiber cable to the fresh water polyp of the genus Hydra. The complexity of the instrument, however, may make inexperienced users feel that the name was selected for the following definition:

> Hydra *n.* A multifarious source of destruction that cannot be eradicated by a single attempt.[1]

We certainly hope that this is not the case. As Hercules required planning and perseverance in conquering the mythical monster Hydra, so should users of the Hydra instrument likewise take the time and effort to carefully plan their strategy and be well prepared for the observing process. In that manner, Hydra shall not be a foe, but rather a friend, capable of providing a wealth of valuable astronomical data.

[1] The American Heritage Dictionary of the English Language

Part II
INSTRUMENT DESCRIPTION/PERFORMANCE

3 INSTRUMENT DESCRIPTION OVERVIEW

Although the typical user need not be intimately familiar with all of the details of the instrument, particularly in this new era of queue observing, it is still very important to have some basic knowledge of Hydra in order to design an optimal observing strategy and program. We give here a basic review of Hydra and its functionality. Those interested in additional information on the instrument design should look at the reference papers listed below.

3.1 REFERENCE PAPERS

Descriptive papers about Hydra and the Bench Spectrograph have been published.

The first three papers address the initial version of Hydra as designed for use on the Mayall 4 meter and cover some of the fundamental aspects of the instrument concept and some instrumental capabilities.

- Barden, S. C. and Rudeen, A. C. (1990), *Kitt Peak National Observatory Fiber Actuator Device*, in Instrumentation in Astronomy VII, ed. David L. Crawford, SPIE Vol. 1235, p. 729.

- Barden, S. C., Armandroff, T., Massey, P., Groves, L., Rudeen, A. C., Vaughnn, D., and Muller, G. (1992), *Hydra – Kitt Peak Multi-Object Spectroscopic System*, in Fibre Optics in Astronomy II, ed. Peter M. Gray, A.S.P. conference series Vol. 37, p. 185.

- Barden, S. C., Elston, R., Armandroff, T., and Pryor, C. P. (1992), *Observational Performance of Fiber Optics – High Precision Sky Subtraction and Radial Velocities*, in Fibre Optics in Astronomy II, ed. Peter M. Gray, A.S.P. conference series Vol. 37, p. 223.

The next two papers address specific modifications to Hydra for use on the WIYN telescope.

- Barden, S. C., Armandroff, T., Muller, G., Rudeen, A. C., Lewis, J., Groves, L. (1994), *Modifying Hydra for the WIYN Telescope: an Optimum Telescope, Fiber*

MOS Combination, in Instrumentation in Astronomy VIII, ed. David L. Crawford and Eric R. Craine, SPIE Vol. 2198, p. 87.

- Barden, S. C. and Armandroff, T. (1995), *Performance of the WIYN Fiber-Fed MOS System: Hydra*, in Fiber Optics in Astronomical Applications, ed. Samuel C. Barden, SPIE Vol. 2476, p. 56.

There have also been numerous scientific papers published in recent years based on Hydra data (obtained during Hydra's tenure on the Mayall telescope). Some recent examples are:

- Caldwell, N., Rose, J. A., Sharples, R. M., Ellis, R. S., and Bower, R. G. (1993), *A.J.* **106**:473.
- Hill, J. M., and Oegerle, W. R. (1993), *A.J.* **106**:831.
- Hillenbrand, L. A., Massey, P., Strom, S. E., and Merrill, K. M. (1993), *A.J.* **106**:1906.
- Massey, P. M. and Armandroff, T. E. (1995), *A.J.* **109**:2470.
- Perelmuter, J.-M., Brodie, J. P., and Huchra, J. P. (1995), *A.J.* **110**:620.

3.2 THE HYDRA FIBER POSITIONER

Table 1 lists a summary of the Hydra fiber positioner characteristics.

3.2.1 The Fiber Cables

Two science fiber cables are currently available on Hydra; one for observations in the red, the other for blue observations. Each fiber in the red cable subtends 2 arc-seconds on the sky while each blue fiber subtends 3 arc-seconds.

On the end of each fiber is mounted a small right angle prism with an aluminized hypotenuse. This fiber/prism assembly, in turn, is mounted in a magnetic "button" which holds the fiber in position on the focal plate. Figure 1 shows a schematic view of this button.

3.2.2 The Focal Plate Assembly

Fibers selected for use are positioned onto a thin, flat, steel plate during target configuration. After all fibers are in place, a vacuum is applied on the back side of the plate to warp it against a spherical backstop. This both draws the fibers onto the true focal surface and aligns them axially with the telescope exit pupil.

HYDRA POSITIONER CHARACTERISTICS	
Full Unvignetted Field Size	60 arc-minutes diameter
Minimum Fiber to Fiber Separation	37 arc-seconds
Positioning Accuracy	0.2 arc-seconds (20μm) estimated
Configuration Time (100 fibers)	20-25 minutes
Total Number of Fiber Slots	288
Number of Guide Fibers (FOPs)	12
Number of Available Science Cables	2
Number of Fibers Per Cable	98 Red, 96 Blue
Fiber Cable Length	25 meters
Blue Cable Spectral Window	3000Å – 7000Å
Blue Cable Fiber Diameter	3.1 arc-seconds (310μm)
Red Cable Spectral Window	4500Å – 1.8μm
Red Cable Fiber Diameter	2.0 arc-seconds (200μm)

Table 1: Summary of the Hydra Positioner characteristics.

Unused fibers are left positioned in either stow or park positions, located around the outer circumference of the assembly. These positions are at a depth lower than the surface of the warpable plate so that fibers in use can cross over unused neighbors.

There are 288 total fiber positions evenly spaced around the focal plate numbered from 0 through 287. The red fibers occupy every third position beginning at location 1 and include an additional two fibers at positions 276 and 279 (spares which can be used with the nominal complement). The blue fibers are also located at a spacing of every third position starting at location 2. The Field Orientation Probes are set at spacing intervals of every 24th with the first occupying position 0. The remaining 82 empty slots are available for future fiber cable implementations.

3.2.3 The Gripper and Stages

To position the fibers, a 3-fingered gripper rides on a 3-axis stage mechanism moving each fiber, one by one, onto the focal plate assembly. The center of the gripper jaw enclosure is optically transparent allowing a gripper camera to "view" the button placement via illumination from a bank of LED's on the gripper.

The Z-axis, allowing the gripper to pick up and place, rides on a Y-stage which in turn is mounted to a dual drive X-stage. Both X and Y stages are encoded to 2.5μm steps (0.024 arc-seconds on the sky). Positional error is estimated to be about 0.2" (20μm) rms.

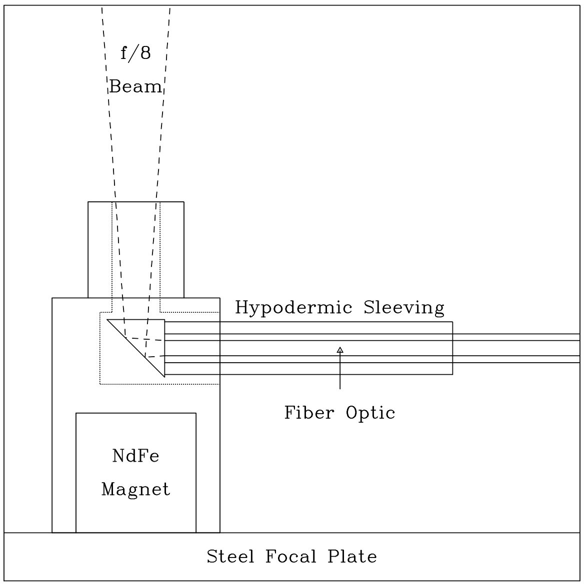

Figure 1: Schematic view of a fiber button on the focal plate.

3.3 CALIBRATION SOURCES

Two banks of 8 hollow-cathode tubes (a Th-Ar and a Cu-Ar set) are located above the focal surface for wavelength calibrations. The lamps illuminate a screen which folds into the beam when in use. Selection of the lamp type is made by swapping a cable connection near the instrument.

Flat field calibrations are made by pointing the telescope at a white spot which is mounted onto the side of the dome. A bank of quartz lamps, mounted on the telescope, illuminate the white spot.

3.4 THE HYDRA GUIDER

Target field acquisition, alignment, focus, and closed loop guiding are controlled by the use of the Field Orientation Probes (FOPS). Twelve such probes are mounted symmetrically about the focal plate. Each probe consists of a 7-fiber coherent array with 1 arc-second fibers.

A TV views the output of all twelve probes for the provision of guider signals and for the visual inspection of the field alignment and the telescope focus.

Since the guider must perform 3-axis guiding (altitude, azimuth, and field rotation), it is absolutely necessary to have at least 2 probes in use within the target field. However, we strongly recommend a minimum of 3 or 4 probes so that astrometry errors can also be somewhat compensated for.

Filters are available for use in the FOPS TV (BG-39, RG610, or clear glass) to optimize alignment with respect to the spectral bandpass being observed.

3.5 THE BENCH SPECTROGRAPH

The Bench Spectrograph is a stable, isolated spectrograph optimized for use with optical fibers. It permits relatively easy changes of configuration between high and low dispersion and between various spectral regions. The bench-mounted nature also allows for future additions and modifications. Figure 2 shows the schematic layout of the Bench Spectrograph.

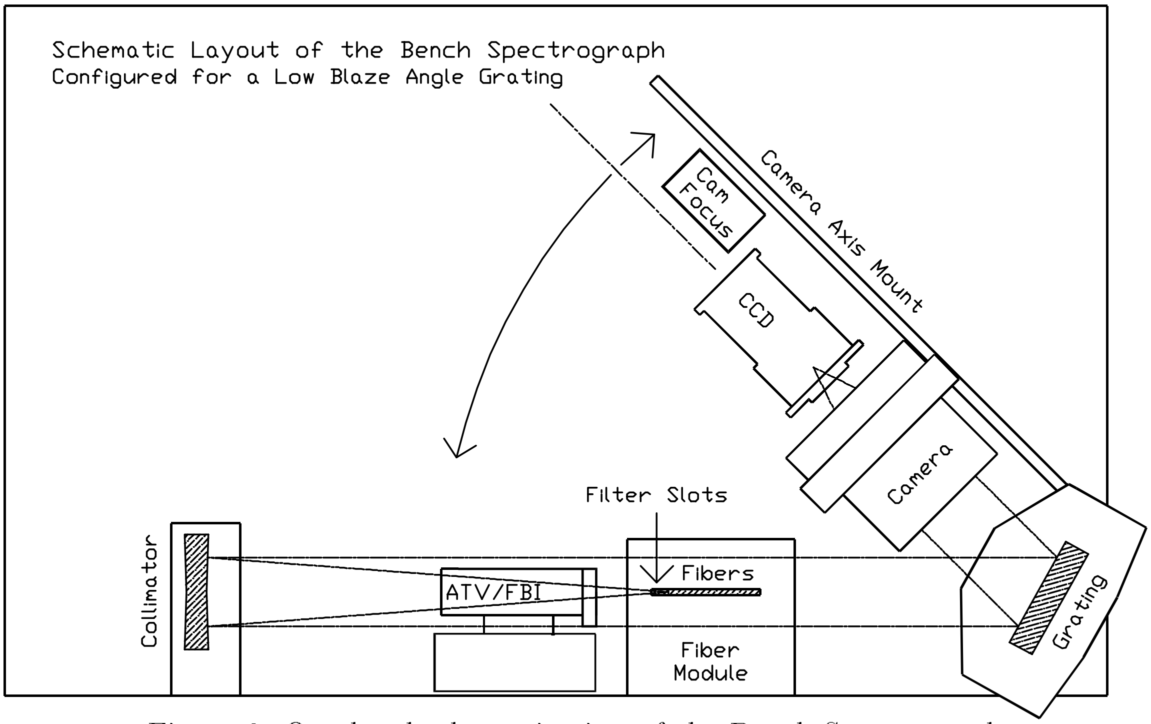

Figure 2: Overhead schematic view of the Bench Spectrograph.

Adjustable components include the choice of blue or red fiber cables, the choice of several gratings, the choice of two cameras, and a variable collimator-camera angle and grating-detector distance.

3.5.1 Summary of Spectrograph Characteristics

The spectrograph characteristics are summarized in Table 2.

BENCH SPECTROGRAPH CHARACTERISTICS	
Available Gratings	See Table 4
Cameras	Simmons Camera (f.l. 381 mm, 3000Å – 1.5μm)
	Bench Camera[1] (f.l. 285 mm, 3800Å – 1.5μm)
Collimator	6 inch f/6.7 Paraboloid
Camera Collimator Angle	Variable between 11° and 45°[2]
Detector	2048 Thinned SITe (24μm–pixels) CCD
Typical Resolution Element	2 to 4 pixels
Spectral Coverage	100Å[3] to ~1 octave[4][5]

[1]Not available until 1996.
[2]Echelle should use 12° while the other gratings should use an angle of 30°.
[3]316@63.4 Echelle.
[4]316@7.0 and 400@4.2 gratings.
[5]ie. greater than the free spectral range of the grating.

Table 2: Summary of the Bench Spectrograph characteristics.

3.5.2 The Fiber Module

The Fiber Module holds the fiber slit (foot) of either the red or blue cable in alignment with the collimator. Collimation adjustment (fiber focus) is made via translation of this unit. Note that only one cable can be mounted on the Fiber Module at any given time.

3.5.3 Filters

There are four filter slots on the Fiber Module. The first slot (A) holds aperture masks and is not currently used; the second slot (B) holds thick (0.35 in) filters (the interference filters for the Echelle grating); the other two (C and D) hold thinner (0.25 in) filters (the glass filters). Hence, it is possible to use a broad-band glass filter in concert with another glass filter or with an interference filter for maximal blocking.

A list of available filters for order separation is given in Table 3. In that Table, LP stands for longpass, BP for bandpass. "λ-" and "λ+" are the half maxima. Transmission curves for the available filters are shown in Figures 3 and 4.

3.5.4 The Bench Acquisition TV and Fiber Back Illuminator

A rear slit viewing TV (called the Acquisition TV or ATV) for viewing the fiber ends is located immediately after the last filter slot.

A bank of LED's called the Fiber Back Illuminator (FBI) is attached to the ATV assembly and is used to back light the fibers while viewing them with the Hydra Gripper TV. When not in use, the FBI is turned off and located off-axis from the ATV.

BENCH SPECTROGRAPH FILTERS						
No.	Filter	Type		$\lambda-$ (Å)	$\lambda+$ (Å)	Notes
G1	RG–610	Glass	LP	6000		
G2	RG–695	Glass	LP	6970		
G3	GG–375	Glass	LP	3750		
G4	GG–420	Glass	LP	4240		
G5	GG–495	Glass	LP	5020		
G6	BG–38	Glass	BP	3370	6230	slight red leak $>1\mu$m
G7	BG–39	Glass	BP	3420	5970	
X6	order 15	Interference	BP	3682	3826	for 316@63.4 echelle
X7	orders 14&15	Interference	BP	3803	3971	for 316@63.4 echelle
X7.5	CaII H&K	Interference	BP	3869	4040	for 316@63.4 echelle
X10	order 13	Interference	BP	4245	4417	for 316@63.4 echelle
X11	orders 12&13	Interference	BP	4392	4654	for 316@63.4 echelle
X12	order 12	Interference	BP	4584	4799	for 316@63.4 echelle
X13	orders 11&12	Interference	BP	4735	5055	for 316@63.4 echelle
X14	order 11	Interference	BP	4983	5252	for 316@63.4 echelle
X16	order 10	Interference	BP	5458	5800	for 316@63.4 echelle
X17	orders 9&10	Interference	BP	5724	6146	for 316@63.4 echelle
X18	order 9	Interference	BP	6006	6492	for 316@63.4 echelle
X19	orders 8&9	Interference	BP	6358	6910	for 316@63.4 echelle
X22	order 7	Interference	BP	7638	8435	for 316@63.4 echelle
X23	orders 6&7	Interference	BP	8159	9194	for 316@63.4 echelle

Table 3: List of Bench Spectrograph filters.

Both the ATV and FBI are removed from the spectrograph beam when not in use.

3.5.5 The Collimator

The collimator is an aluminum-coated parabolic mirror producing a 152 mm (6 inch) beam (per fiber).

3.5.6 The Grating Module and Gratings

The Grating Module holds large gratings, such as the 206 by 406 mm echelle (grating 316@63.4), one at a time. Grating angle is remotely adjusted and set by this unit.

The parameters for the available gratings are listed in Table 4.

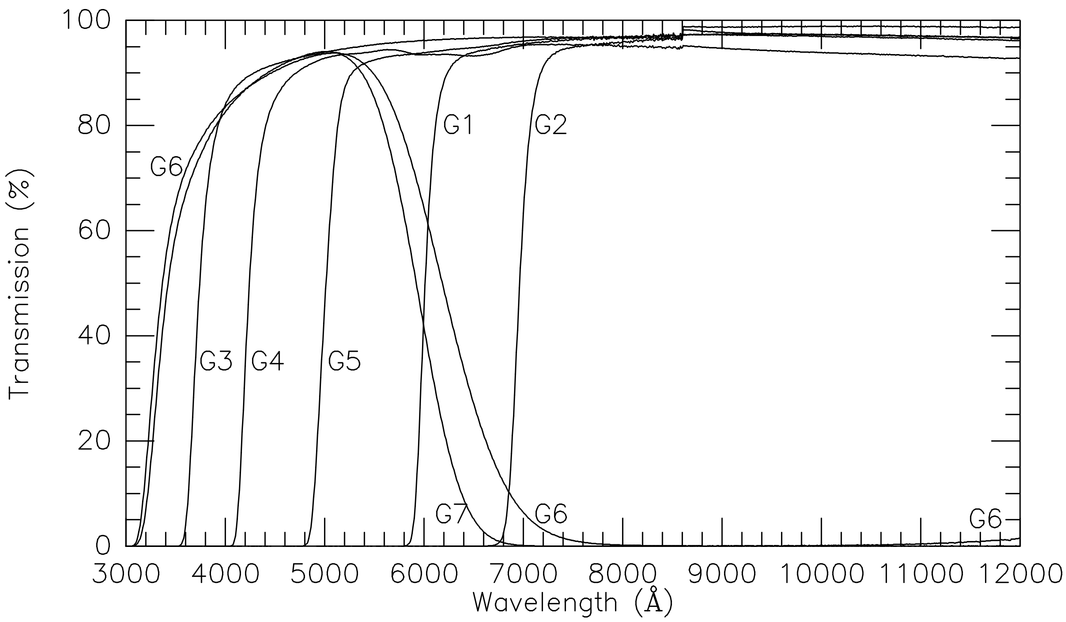

Figure 3: Transmission curves for the available glass filters. Note the red leak in the G6 filter. The glitches at 8600 Å are artifacts from the scanning process.

BENCH SPECTROGRAPH GRATINGS

Grating	l/mm	Blaze Angle	Peak Efficiency	Size (mm)	Notes
316@7.0	316	7.0°	70%	203 × 230	Similar to BL181
400@4.2	400	4.2°	70%	203 × 230	First Order Blue
600@13.9	600	13.9°	70%	203 × 230	Similar to BL420
860@30.9	860	30.9°	65%	203 × 230	Similar to KPC-24
1200@28.7	1200	28.7°	55%	203 × 230	Similar to BL380
316@63.4	316	63.4°	50%	206 × 406	Echelle grating

Table 4: List of Bench Spectrograph gratings.

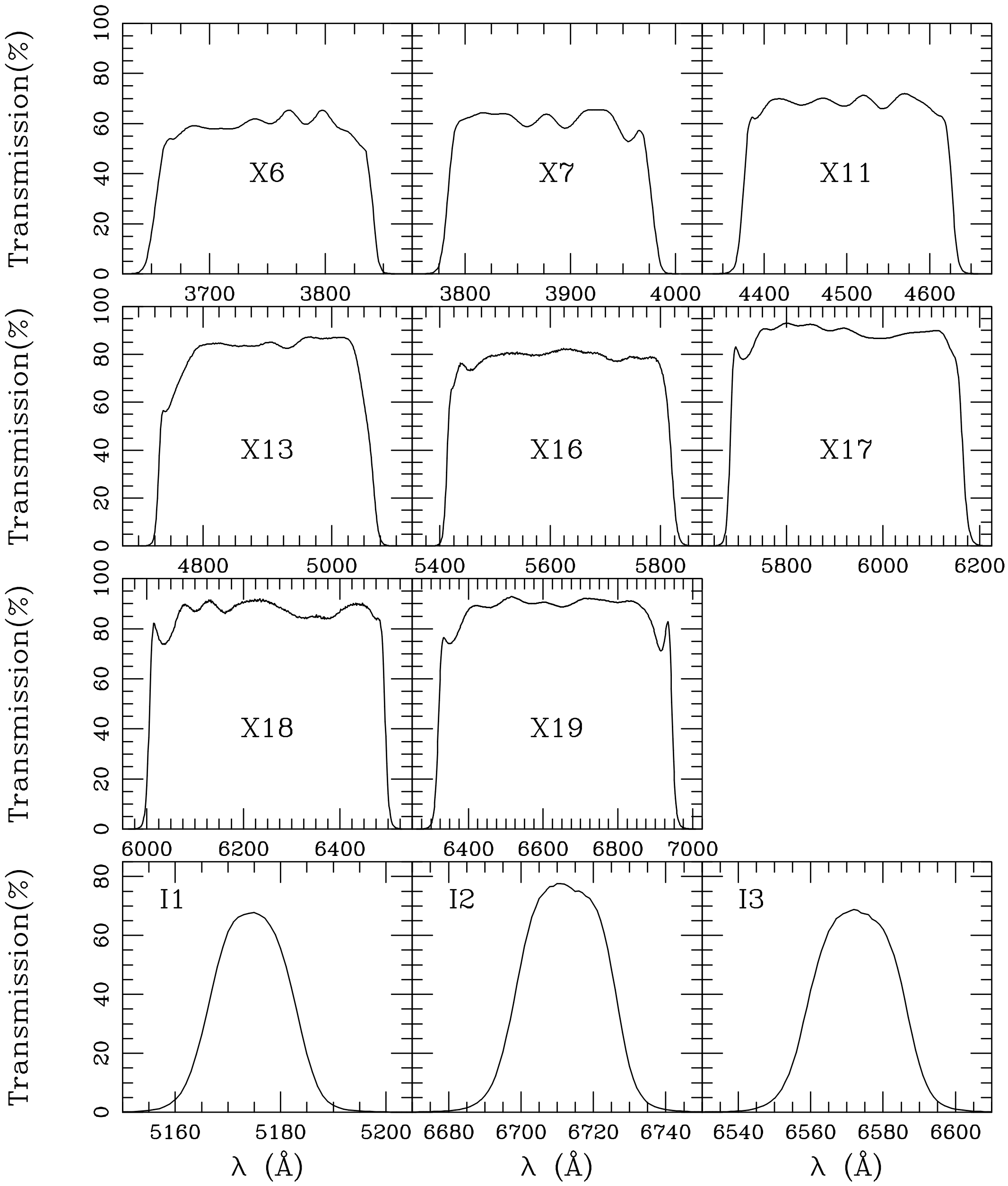

Figure 4: Transmission curves for the interference filters.

Efficiency curves for the Bench Spectrograph gratings are displayed in Figure 5. Note

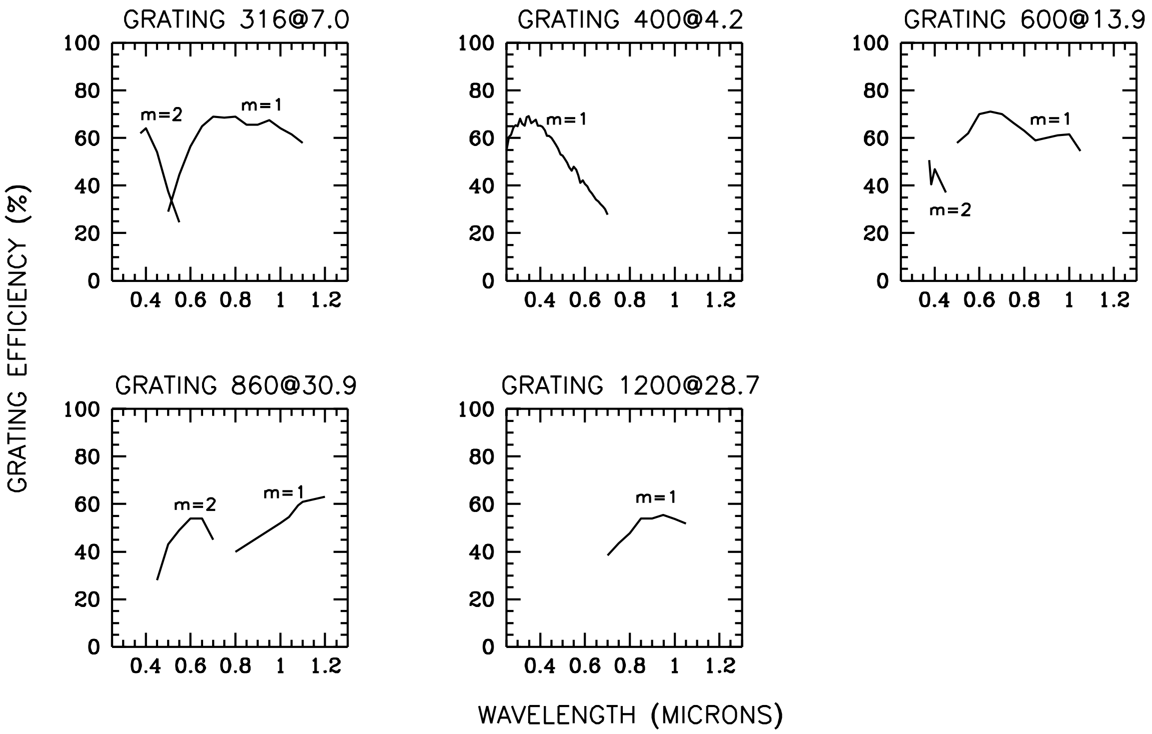

Figure 5: Blaze efficiency curves for gratings 316@7.0, 400@4.2, 600@13.9, 860@30.9, and 1200@28.7.

that the curves for gratings 316@7.0, 600@13.9, 860@30.9, and 1200@28.7 are taken from the RC gratings of similar characteristics and for a camera-collimator angle of 45 degrees. The 400@4.2 curve was measured with the actual grating at Milton-Roy for an angle of 30 degrees.

3.5.7 The Camera Axis Mount

The camera axis mount extends from under the Grating Module to provide for rotation of the camera about a vertical axis through the center of the front surface of the grating. This allows the camera-collimator angle to be varied between 11 and 45 degrees. The camera-grating distance can also be varied along the camera axis in order to place the camera mouth as close to the grating surface as possible without vignetting the light path from the collimator to the grating.

A camera-collimator angle of 12 degrees is typically used for the echelle grating (316@63.4) when used with the Simmons camera and 11 degrees when used with the Bench Spectrograph Camera. The low blaze angle gratings should normally use an angle of 30 degrees.

T2KC CHARACTERISTICS	
Character	Quantity
Readout Noise	4.3e$^-$
Recommended Gain	1.7e$^-$/ADU (gain index = 4)

Table 5: Characteristics of the T2KC CCD.

3.5.8 The Simmons Camera

The Simmons Camera (formerly from the Mayall RC spectrograph) is of the Cassegrain Mangin-Mirror Maksutov type, employing two corrective meniscus lenses. The focal length is 381 mm.

The throughput of the Simmons Camera is flat at 45%. This crosses the expected throughput curve of the Bench Spectrograph Camera at about 3800 Å. The Simmons Camera should be used for observations that extend blueward of about 3800 Å.

3.5.9 The Bench Spectrograph Camera

A 285 mm focal length, all-transmission camera, optimized for use between 4500 and 7300 Å with a 24 μm-pixel SITe 2048x2048 CCD, has been fabricated. The camera will be usable from slightly blueward of 4000 Å out to 12000 Å with a refocus.

This camera is under final development. We hope to have it in use by early 1996.

3.5.10 The Detector

The Bench Spectrograph uses the T2KC chip, a thinned SITe 2048x2048 CCD with 24 μm-pixels. The Hydra spectra are aligned along the columns of this CCD.

Figure 6 shows the quantum efficiency curve for the CCD. Table 5 lists the readnoise and recommended gain of the CCD.

3.5.11 The Camera Focus Module

This unit translates the CCD with respect to the camera for final focus.

Spectrograph focus is achieved by placing the fibers into collimation with the Fiber Module (see section 3.5.2 on page 8) followed with a focus sequence obtained by moving the CCD with respect to the camera via the Camera Focus Module.

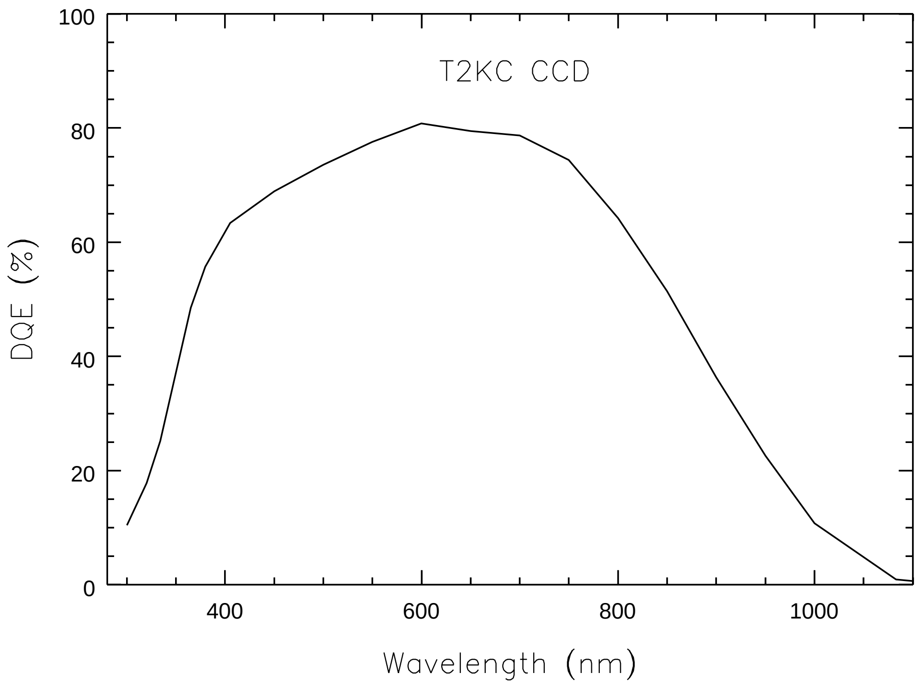

Figure 6: Quantum Efficiency of the T2KC CCD.

3.5.12 The Simultaneous Comparison Sources

Two fibers, located at either end of the "slit" assembly, connect to comparison sources located near the Bench Spectrograph. This permits comparison light exposures to be made over the course of a target field integration. Such ability to monitor the wavelength zero point may be useful for programs seeking to measure high-precision radial velocities. The comparison source choices are Th-Ar or Cu-Ar with the added availability of a quartz lamp for the aperture/flat field definition of those two fibers. Neutral Density filters are used to adjust the illumination of the Simultaneous Comparison Sources (SCS).

3.5.13 Sample Bench Spectrograph Capabilities

Table 6 gives some specific sample spectrograph parameters for the available gratings. This table should provide a rough guideline to spectral coverage and resolution for each available grating. The final custom setup should be explored using the program *setup.f* (see Section 7.1 on page 29).

SAMPLE BENCH SPECTROGRAPH CONFIGURATIONS								
Grating	Central λ (Å)	Order	λ Coverage (Å)		Spectral Resolution (Å)		Dispersion (Å/pixel)	
			Simmons	BSC[1]	Red Cable[2]	Blue Cable[3]	Simmons	BSC
316@7.0	7500	1	4000	5400	5.72	8.87	1.97	2.64
316@7.0	3750	2	2000	2700	2.86	4.44	0.99	1.32
400@4.2	5000	1	3200	4250	4.56	7.07	1.56	2.08
600@13.9	7500	1	2150	2900	2.86	4.43	1.05	1.40
600@13.9	3800	2	1075	1450	1.43	2.22	0.53	0.70
860@30.9	10800	1	1500	2000	1.64	2.54	0.71	0.95
860@30.9	6000	2	720	960	0.77	1.19	0.35	0.47
860@30.9	4000	3	480	640	0.52	0.80	0.23	0.31
1200@28.7	7500	1	1050	1400	1.19	1.84	0.51	0.68
1200@28.7	4000	2	520	700	0.58	0.90	0.25	0.34
316@63.4	6563	9	200	270	0.16	0.25	0.10	0.13
316@63.4	3890	14	175	230	0.17	0.27	0.08	0.11

[1]Transmission of the Bench Red camera cuts off blueward of 3900Å.
[2]Transmission of the red fibers cuts off blueward of 3900Å.
[3]Transmission of the blue fibers cuts off redward of 8000Å.

Table 6: Sample Bench Spectrograph configurations.

3.6 INSTRUMENT COMPUTERS

There are two computers and consoles from which the full operation of Hydra and the Bench Spectrograph take place:

- Oatmeal – A Sun IPX computer for Hydra positioner operation.
- Vanilla – A Sun SPARCstation 10 used for operation of the ArCon CCD and the Bench Spectrograph.

4 INSTRUMENT PERFORMANCE

Several factors determine the performance level of the instrument. Instrumental factors governing the throughput are the transmission characteristics of the fiber optics, quality of the prism mountings, optical axis alignment of the fiber at the telescope and in the spectrograph, focal ratio degradation within the fibers, grating efficiency, camera throughput and vignetting, presence of central obstructions, detector efficiency, and quality of the coatings on the various optical components within the spectrograph and telescope. Environmental factors that can impact the peak instrumental performance include seeing, image quality and focus, atmospheric transparency, and external stresses on the fiber cable. Additional factors that can vary efficiency between target fields arise from astrometry errors and fiber positioning errors.

4.1 FIBER SPECTRAL TRANSMISSION

Figure 7 shows the transmission characteristics of the fiber optics. Both red and blue fiber

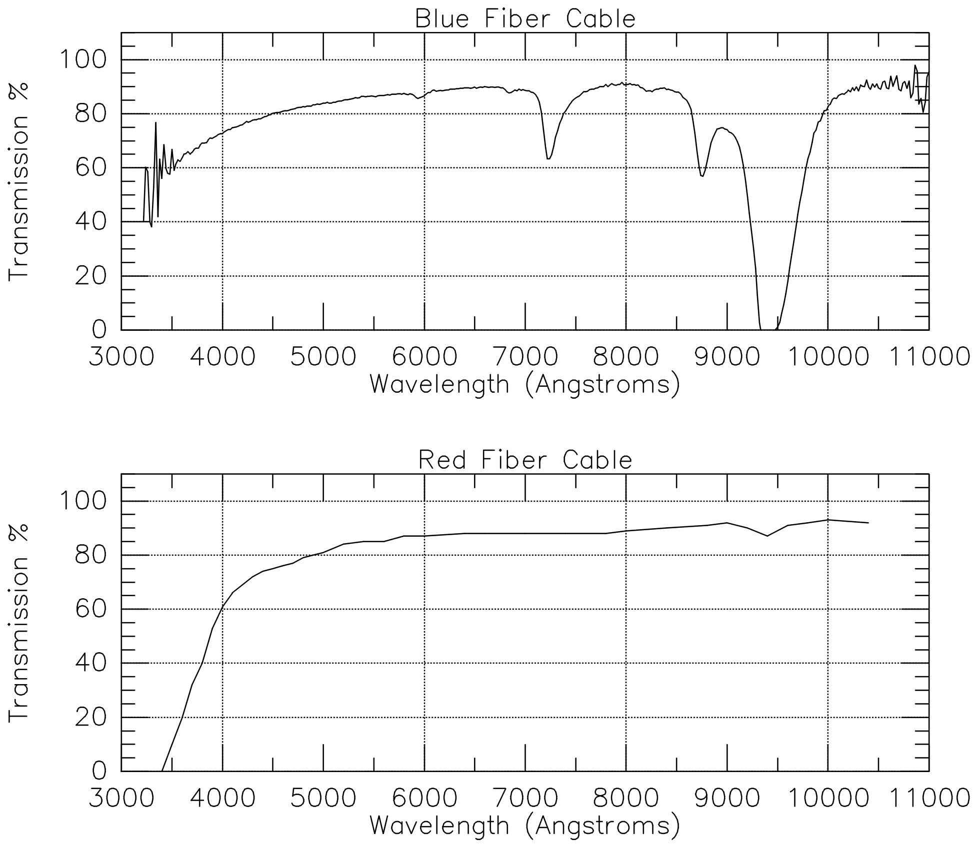

Figure 7: Fiber transmission curves.

cables are 25 meters in length. These curves include end reflection losses, but do not include the additional loss (maybe 5-10%) that may be present from the small prism epoxied onto the fiber end. Focal ratio degradation losses are also not included. The focal ratio of the spectrograph collimators are f/6.7 and should collect >95% of the light contained within the output cone of the fibers.

4.2 FIBER TO FIBER THROUGHPUT

Fiber to fiber throughput variations do exist. The top half of Figure 8 shows a typical cross section of a flat field obtained for the red fiber cable. A similar cross section is shown

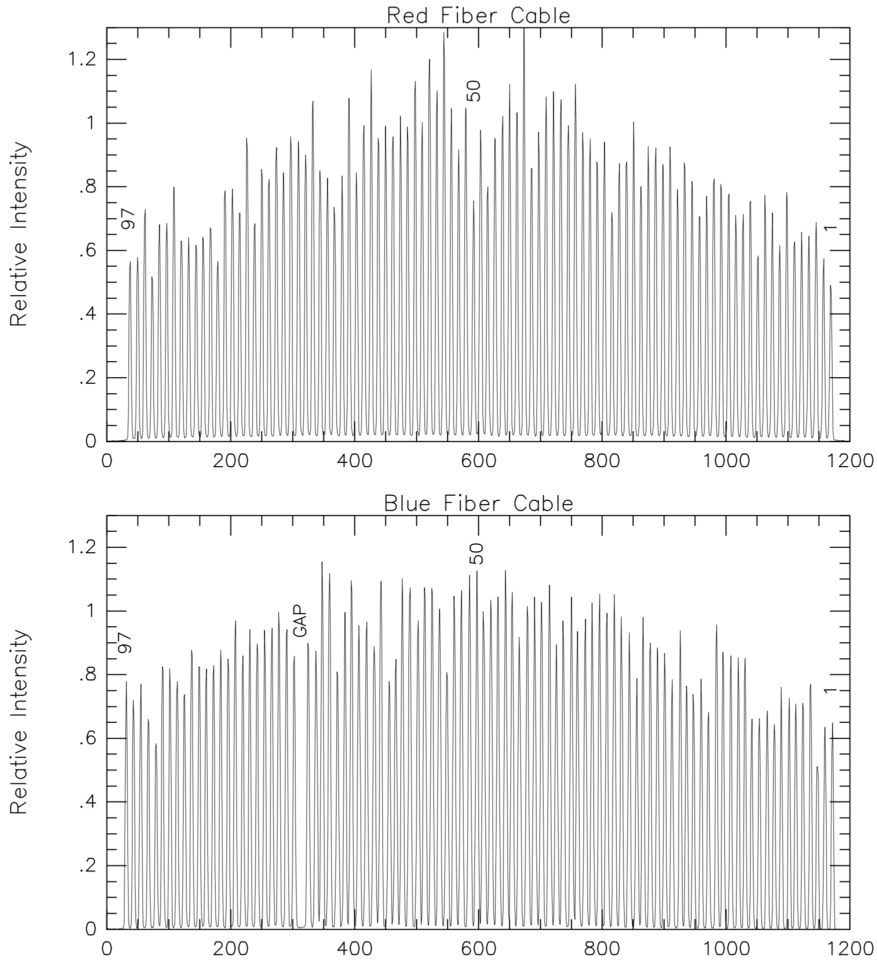

Figure 8: Cross section plot of spatial profiles. UPDATED FIGURE NOT YET AVAILABLE

in the bottom half of Figure 8 for the blue cable. These fiber-to-fiber differences are most likely due to the quality of the prism attached to the input end of the fiber and inherent stresses in each fiber. Spectrograph vignetting across the spatial dimension is apparent in both figures.

4.3 SEEING, POSITIONING, AND ATMOSPHERIC LOSSES

The fiber diameter for the red cable corresponds to 2 arc-seconds on the sky while the blue fibers subtend 3 arc-seconds. Seeing losses should be minimal when the seeing FWHM is on the order of one-half of the fiber aperture. If the FWHM of the seeing profile is equal to the diameter of the fiber aperture, then the seeing losses will be about 50%. Throughput will degrade rapidly as the seeing increases beyond the size of the fiber.

Positional errors in fiber placement onto point sources can also lead to throughput losses.

Note that the WIYN does not have an atmospheric dispersion compensator for the Hydra field. Wide band spectral observations that extend into the blue may be compromised for observations made at airmasses of 1.5 or larger.

The following references provide estimates of fiber losses due to seeing, positional error, and atmospheric dispersion.

Donnelly, R.H., Brodie, J.P., Bixler, J.V., and Hailey, C.J. (1989), *P.A.S.P.***101**:1046.

Brodie, J.P., Lampton, M., and Bowyer, S. (1988), *A.J.***96**:2005.

4.4 FIELD VIGNETTING

There should be no vignetting across the full 60 arc-minute field of view. Note, however, that there is some spectrograph vignetting referred to in Figure 8 on page 17.

4.5 MEASURED SYSTEM THROUGHPUT

INCOMPLETE

NOTE: The following is still based on discussion from the old manual. New data has been obtained, but has not yet been fully reduced into a format for inclusion into the present document. Performance, however, is comparable to that when Hydra was in use on the Mayall telescope.

Peak system throughput (ratio of detected photons to number incident on the primary mirror) can be as high as 5% in the red under good seeing conditions (FWHM seeing of 1.0 arc-seconds) on a fiber that is placed at the center of the field.

Figure 9 shows the number of photons per second per Å detected for the standard star Feige 66 (mλ3500=9.8, mλ4500=10.1, mλ5000=10.3) observed with the blue cable, 860@30.9 grating, T2KB CCD detector, and the Simmons Camera. The dropoff on the blue end is dominated by atmospheric extinction and the rapidly declining quantum efficiency of the CCD detector. The grating blaze function and color of the star are the predominant terms defining the slope on the red end of the spectrum.

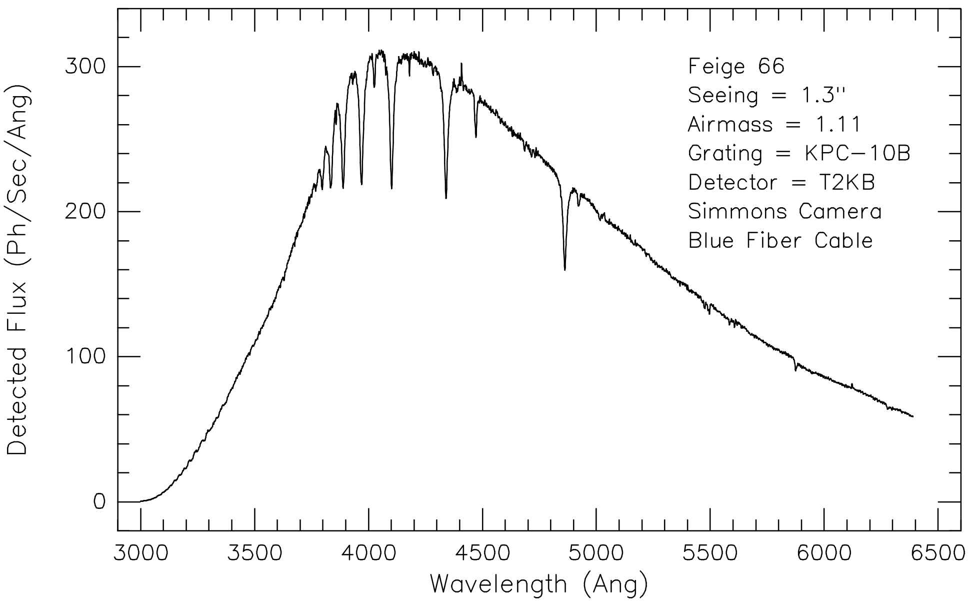

Figure 9: Flux counts with the blue fiber cable. UPDATED FIGURES NOT YET AVAILABLE

Estimates of exposure time can be extrapolated from Figure 9 by scaling the grating dispersion and blaze efficiencies, CCD QE, fiber throughput, filter transmission, and object magnitudes.

4.6 FLAT FIELD EXPOSURES

Typical single exposure times on the dome flats, using the high intensity lamps, will range from 10-30 seconds for low dispersion observations to 600-900 seconds for high dispersion observations with the echelle gratings.

4.7 WAVELENGTH CALIBRATION EXPOSURES

The typical exposure times for the wavelength calibration lamps can range from 300 to 900 seconds depending on spectral region and choice of lamp (Th-Ar or Cu-Ar).

4.8 SPECTROGRAPH SCATTERED LIGHT

INCOMPLETE

There may be low level background light with some of the gratings. Figure 10 shows the typical pattern of scattered light for various fibers when using the 400@4.2 grating.

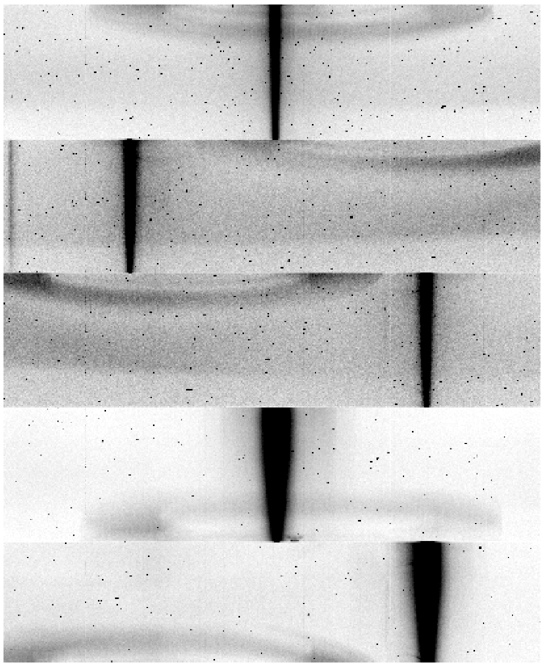

Figure 10: Scattered light images for the 400@4.2 grating. UPDATED FIGURE NOT YET AVAILABLE

Keep in mind that scattered light is additive according to the illumination level of each fiber. With all fibers equally illuminated (as in a flat field), the scattered light contamination may be as large as 5% in some regions. On the target fields, faint objects will suffer from contamination when brighter objects are observed at the same time. To minimize the effects of scattered light contamination on the faint spectra to less than 5%, the brightness range of the targets should not exceed about 4 to 5 magnitudes. A magnitude range of 3 has proven to be ideal under most circumstances.

User verification of the scattered light can be carried out by observing a bright star down one fiber or by taking a strong exposure of the quartz lamp in the Simultaneous Comparison Source.

There are fiducial gaps in both fiber cables for the monitoring the background contamination.

The **dohydra** routine in iraf contains the option of fitting the scattered light as part of its process (an equivalent to the iraf **apscatter** routine).

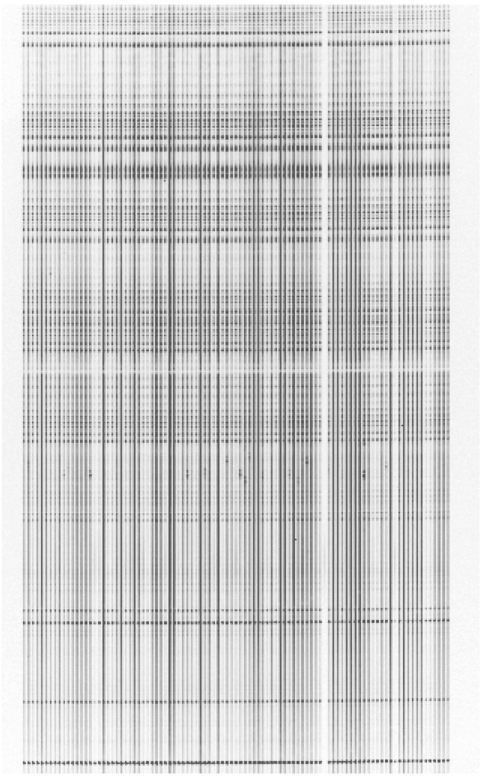

Figure 11: Sample data frame.

4.9 SAMPLE DATA

Figure 11 shows a sample data frame obtained with Hydra (while at the Mayall) on a cluster of galaxies.[2] The spectra cover from 5500-9500 Å. Roughly 70 galaxy spectra were detected in this 1.3 hour exposure. H-alpha emission can be seen in several of the spectra. An extracted spectrum (sky subtracted) is shown in Figure 12.

[2]Data courtesy of Oegerle, Barden, and Hill

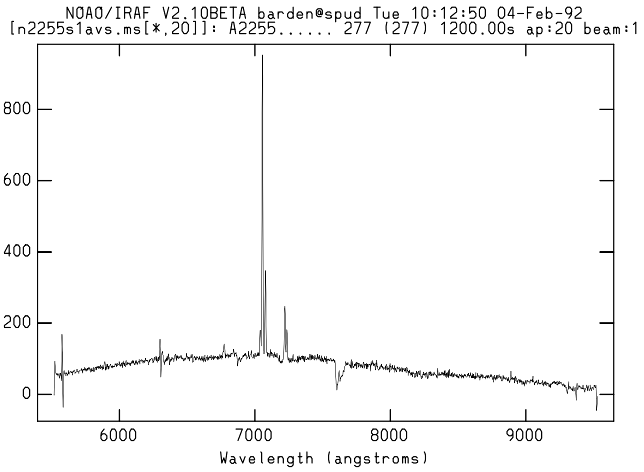

Figure 12: Sample spectrum.

Part III

OBSERVING RUN PREPARATION AND INSTRUMENT OPERATION

5 GENERAL OBSERVING RUN PREPARATIONS

The following guideline should be used in preparation of an observing run which uses Hydra. **NOTE: Preparation for a Hydra run should ideally start several weeks prior to the telescope time.**

- Obtain good astronomical coordinates for your target objects.

  Good astrometry means relative coordinates to better than 0.5 arc-seconds with all targets in the field derived from the same reference frame.

- While doing the astrometry, measure the positions of several non-program stars (10<V<15) for use as field orientation stars.

  The more stars measured, the less impact FOPS assignment will have on the science target assignments.

At least 2 stars are required (preferably toward the edges of the field). We suggest that more than 3 Field Orientation Probes are actually assigned in order to provide redundancy in the correction of astrometric errors and field rotation.

These stars should also span a relatively small magnitude range (<2 to 3 mags) so that each star can be seen on the TV at the same gain.

- Measure lots of sky positions if sky subtraction is important.

  Again, the more positions available to the assignment algorithm, the less impact the sky assignments will have on getting fibers to the target objects.

- Obtain copies of the manuals and available software (see below).
- Read the manuals!
- Run the assignment code on your fields.

  The assignment manual gives a description of how the assignments are made. Familiarization with this process prior to completion of the astrometry may allow better selection of sky and field orientation star positions.

- After running some fields through the assignment code, try out the Hydra simulator (only available on Sun window systems) to view those assignments.
- Iterate on your assignments and produce the final assignment files for the observing run.
- Run the spectrograph setup program to determine the configuration desired.
- Fill out and submit either the Observing Run Preparation Form or the WIYN queue forms depending on whether you will be on site as the observer or whether you will be participating in the NOAO queue program.
- Contact any of the staff contacts for answers to unresolved questions.
- First time users are strongly encouraged to seek advice.
- Provide us with useful criticism at the end of the run so that we can attempt to smooth out Hydra's operation.
- Hope for clear weather and have a productive run!

6 MANUALS AND SOFTWARE ACCESS

6.1 AVAILABLE MANUALS

There are 3 manuals required for Hydra use.

- Hydra/WIYN Users Manual (this manual)

  This manual describes the operation of the fiber positioner and the Bench Spectrograph.

- Hydra: A Program for Assigning Fibers

  This manual describes the use of the assignment algorithm which determines which fibers are assigned to which target objects.

- The WIYN ArCon-IRAF Interface: A User's Guide

  This manual describes operation of the CCD.

6.2 AVAILABLE SOFTWARE

The following software is available for use at the observer's home institution as an aid in preparation for the observing run.

- *setup.f* – Spectrograph Configuration Software

  This program allows the user to model the spectrograph configuration for optimization of the spectral setup. The routine is written in FORTRAN and is easily transportable to various computers.

- *whydra.f* – Assignment Program

  The user will need this routine in order to properly assign the available fibers onto the target objects. The program is a combination of both FORTRAN and C (a library called *kaboomlib.a*). The C component currently requires a Unix environment on a Sun computer.

  This is the most important program for observing run preparation. The user should obtain this program several weeks prior to the observing run in order to have sufficient time for determining and optimizing the fiber assignments.

- *fiborg*4.0.0 – Hydra Simulator

A Hydra simulator is available that allows the user to view the assignments and practice operation of the instrument. The programming is written in C and TK. It currently requires a Sun workstation running OpenWindows for the graphics.

6.3 ACCESS TO MANUALS AND SOFTWARE

You can access current versions of the software and manuals through the ftp facility. Follow the steps listed below.

6.3.1 FTP Access of Hydra Manuals and Software

Copies of the assignment code and manual(s) are kept on the NOAO anonymous ftp area. To obtain copies of everything, do the following:

- change to the directory you would like to copy the manuals and software to on your machine.
- **ftp ftp.noao.edu**
- login as **anonymous**
- give your email address for the password.
- ftp>**cd kpno/hydra**
- ftp>**prompt**
- ftp>**binary**
- ftp>**mget ***

  Use this only if you desire to get all of the files located in that area. This will transfer the files:

  - README
  - whydra.f [FORTRAN source code for the assignments]
  - kaboom.tar.Z [C stuff needed for the assignments]
  - concentricities [The fiber cross reference used by whydra.f]
  - hydra.ps.Z [the assignment user manual]
  - hydramanual.ps.Z [the user manual for the instrument]

  - fiborg.tar.Z [the Hydra simulator code, NOT YET AVAILABLE] Note that the version number of the code will be part of the file name as in fiborg4.0.0.tar.Z.
  - setup.f [Bench Spectrograph setup software]
  - sample.in [sample input astrometry file for whydra.f]
  - sample.hydra [sample output configuration file from whydra.f]
  - other documents regarding Hydra as they become available

  Use **get** <*filename*> instead of **mget** * to get specific files.

- ftp>**bye**

6.3.2 Printing the Assignment Manual

To print the assignment manual, do the following:

- **uncompress hydra.ps.Z**
- **lpr -PlwN hydra.ps**

6.3.3 Printing the Hydra/WIYN Users Manual

The Hydra/WIYN Users Manual can be printed with the same commands:

- **uncompress hydramanual.ps.Z**
- **lpr -s -PlwN hydramanual.ps**

  The **-s** flag may be needed to print the manual file without truncation. It's a large file!

6.3.4 Compiling the Assignment Code

To make the assignment code, you must do the following:

- **uncompress kaboom.tar.Z**
- **tar -xf kaboom.tar**
- **make**

This will compile the various C files into an archive called kaboomlib.a After kaboomlib.a has been generated, you may delete all subdirectories and files except whydra.f, concentricities, and kaboomlib.a.

We will soon experiment with giving access to precompiled versions of kaboomlib.a which will eliminate the excess files.

Finally, compile the FORTRAN code and link to this library by

- **f77 whydra.f kaboomlib.a -o whydra**

This will generate the assignment code "whydra". After whydra has been generated, you will only need the whydra executable along with the concentricities file for running the program on your input astrometric files.

6.3.5 Compiling the Bench Spectrograph Setup Code

The Bench Spectrograph setup software can be compiled by

- **f77 setup.f -o setup**

6.3.6 Setting Up the Hydra Simulator

The Hydra simulator software can be generated with the following list of commands. (Note that this software will currently only run under OpenWindows on a Sun workstation.)

- Create the required "fiborg" directory from your home directory

  mkdir fiborg

- Change to that directory

  cd fiborg

If a version of the program was already in place, the old files and directories should be deleted. Please make certain that you are in the appropriate directory prior to deleting your files.

"rm" -r *

The quotes around the **rm** command will override any alias you might have for verifying the file deletion. You may also have to delete a few .* files in the fiborg directory which may remain after the generic file deletion.

The .fiborg file in your home directory should also be deleted prior to making the new version of the simulator.

- Move the fiborg.tar.Z file into the "fiborg" directory.
- Unpack the files and make the binaries.

  zcat fiborg*.tar.Z | tar xf - ; make

  Note that the space between the **xf** suffix and the **-** (dash) character is critical!
  This command will take several minutes (about 10) to extract the files and create the additional sub-directories. Two directories in the home directory will also be created (~/fields and ~/fiblogs) if they weren't already in place. If the ~/fields directory was already in place, be assured that those files will not be deleted or modified.

- Change back to your home directory and include in the "set path" command of either your .login or .cshrc file the following path

  ~/fiborg/bin

- Move your target fields into the ~/fields directory.

  This directory may also be the place where you will want to setup the assignment program.

- Log out and back in to allow the new path to be activated or type

  source ~/.login (or **source ~/.cshrc**)

- The Hydra simulator code can now be started with

  hydrasim

NOTE: For those familiar with setting environment variables, it is possible to place the fiborg directory in a location other than that suggested here. The various environment variables are located in the .fiborg file.

6.3.7 To Access and Print the ArCon CCD Manual

In order to obtain a copy of the ArCon manual for operating the CCD, do the following:

ftp ftp.noao.edu

login as **anonymous**

cd wiyn/arcon

get wiynarcon.0.6.ps

bye

7 BENCH SPECTROGRAPH USE

7.1 DESIGNING A SPECTROGRAPH CONFIGURATION

As described previously, the camera-collimator angle on the Bench Spectrograph is variable for increased flexibility. Because of this extra free parameter, and because of the large number of gratings usable with the Bench Spectrograph, we provide a computer program, *setup.f*, to facilitate the calculation of spectrograph parameters. A sample run of the program is shown below. (See also Table 6 on page 15 for some starting points.)

The only camera currently usable with the Bench Spectrograph is the Simmons camera. The Bench Spectrograph Camera is expected to come on line in early 1996.

7.1.1 Sample Run of Spectrograph Setup Program

Below is an example run of *setup*, using the 860@30.9 grating in the vicinity of the Mg triplet.

```
vanilla% setup


 STARTING WIYN/BENCH SETUP PROGRAM


 enter desired central wavelength in Angs....
5170.0
 enter camera selection (1=Red Lens or 2=Simmons)...
2


 the available WIYN gratings are:

  1 = 316@7.0    316 l/mm,  7450A first order
  2 = 400@4.2    400 l/mm,  3800A first order
  3 = 600@13.9   600 l/mm,  7700A first order
  4 = 860@30.9   860 l/mm, 11500A first order
  5 = 1200@28.7 1200 l/mm,  7700A first order
```

```
  6 = 316@63.4   316 l/mm,  63.4 degree echelle
  7 = other

 enter the number of the grating....
4


 SET-UP FOR THE WIYN/BENCH SPECTROGRAPH (ON-AXIS)

 COLLIMATOR                      DETECTOR (T2KC)
 diameter (mm):        150.      pixel number, size: 2048.   24.
 focal length (mm):  1023.6      rdnoise, gain:        4.3    1.7
 focal ratio:          6.00      overall size (mm):   49.2

 GRATING (860@30.9  )            CONFIGURATION
 lines per mm        860.00      camera-coll angle:   30.
 blaze angle:         30.90      use angle (alpha):   42.406
 selected order    2(  2.23)     beta:                12.406

 CAMERA (Simmons )               FIBER DIAM.  (Red Cable )
 focal length (mm):   381.0      in mm:                0.200
 focal ratio:          1.92      in arc-sec            2.00
 mono. beam diam. (mm): 198.

 SPECTRAL PARAMETERS
 central lambda:      5170.      dispersion (A/mm):   14.903
 lower lambda:        4804.      dispersion (A/pix):   0.358
 upper lambda:        5536.      resolution:            6163.

 DEMAGNIFICATION                 SLIT IMAGE
 spectral:             3.55      in mm:                0.056
 spatial:              2.69      in pixels:             2.35

 ESTIMATED OBSERVING AND PERFORMANCE PARAMETERS
 magnitude:           16.00      summed e-/pix:         260.
 exp. time (sec):      600.      summed adu/pix:        100.
 seeing (arc-sec):      1.0      s/n per summed pix:     14.


 0 = save to wiyn.setup   5 = exposure time
```

```
 1 = quit (no save)       6 = fiber diam. (mm)
 2 = wavelength           7 = grating
 3 = magnitude            8 = camera/config
 4 = seeing               9 = detector

  enter 0-9 to change the parameter listed above:
0

 0 = save to wiyn.setup   5 = exposure time
 1 = quit (no save)       6 = fiber diam. (mm)
 2 = wavelength           7 = grating
 3 = magnitude            8 = camera/config
 4 = seeing               9 = detector

  enter 0-9 to change the parameter listed above:
1
vanilla%
```

7.2 BENCH SPECTROGRAPH SOFTWARE CONTROL

The Bench Spectrograph is controlled via a graphical user interface on Vanilla.

DESCRIPTION OF FUNCTIONALITY NOT YET AVAILABLE.

An example of the Bench GUI is shown in figure 13 and figure 14.

8 HYDRA INSTRUMENT USE

8.1 SUGGESTIONS FOR CREATING THE TARGET FIELDS

The following hints should aid in defining the target fields.

8.1.1 Target Selection

- Minimum fiber-to-fiber placement distance is 37 arc-seconds. Remember that button to tube interactions will also govern how close together the fibers can be assigned and that each fiber can only reach to field center and deflect to 10 degrees on either side.

- Keep the magnitudes of the targets in a given assignment to within a range of 3 to 4. Scattered light may compromise the spectra of the faint objects if the range is much

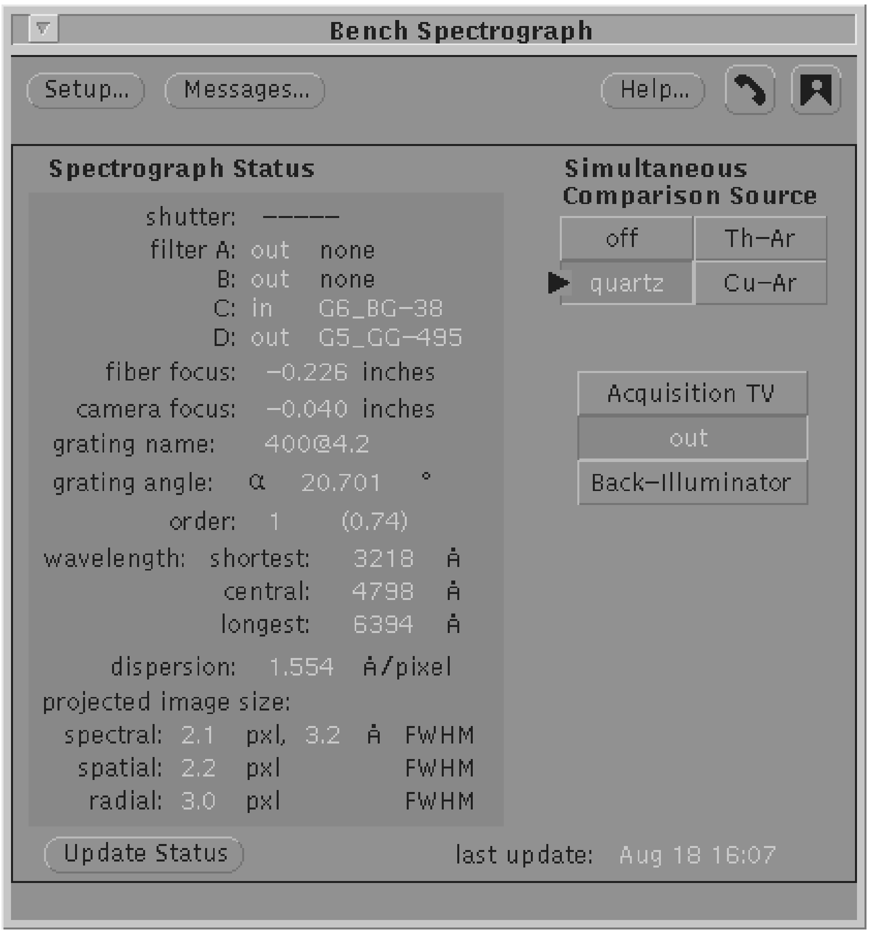

Figure 13: Sample view of the primary Bench Spectrograph GUI window.

larger than this.

8.1.2 Sky Positions

- Select many (we mean lots, many more than will get assigned) sky positions so that fibers can get assigned to the desired number of them with minimal impact on the assignment to target objects.

- In cases where sky is important, but not dominating the signal, on the order of a dozen fibers should probably be assigned to observe the sky. It is ideal to measure blank sky positions in all cases, but random sky positions are probably OK in many situations. Try generating lists of a few hundred random coordinates located on the circumference of circles of varying radii (5 to 30 arc-minutes) centered on the field.

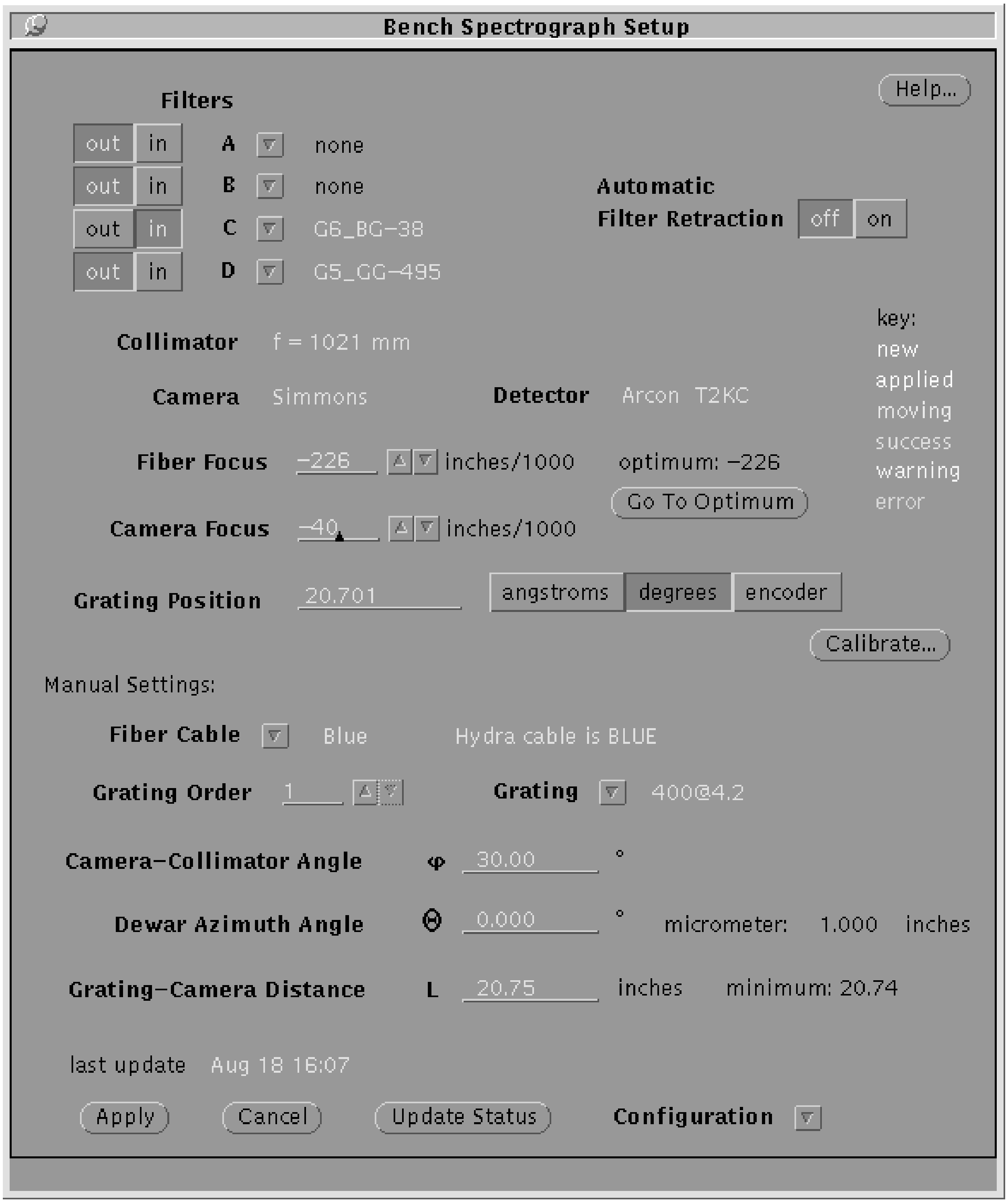

Figure 14: Sample view of the Setup Window for the Bench Spectrograph GUI.

The biggest danger of the random sky positions is the risk that a sky fiber will be placed on or near field stars, particularly in crowded fields.

- For objects that are fainter than the sky, more care is required to hand select blank regions of sky. Again, select many positions. Probably half of the fibers should be dedicated to sky. Designing your field to allow telescope beam switching may be beneficial for the best sky subtraction (unfortunately, we don't have any algorithms for generating beam switching configurations).

8.1.3 Field Orientation Star Selection

- At least 2 Field Orientation Probes must be assigned in order to "lock" the telescope onto the target field. We suggest, however, that 3 or more probes be assigned (1 near field center, two near the edges of the field) to provide redundancy and to serve as a check on astrometric "goodness" and other possible fiber placement errors.

- Since assignment to a field orientation star can impact the assignment of fibers onto neighboring target objects, select several times more potential field orientation stars than are needed and let the assignment routine find the ones that have the smallest impact on neighboring fiber assignments.

- The stars selected for use by the Field Orientation Probes should fall in the magnitude range between m=10-15. (If there are clouds and/or the seeing is larger than 1 arc-second, stars fainter than 15th may not be visible with the FOPS TV camera.)

- If possible, keep the range in magnitude of your FOPS sample to 2 magnitudes or less so that the intensity of each star falls within the dynamic range of the FOPS TV camera.

- Make absolutely certain that the stars selected for use by the Field Orientation Probes have good astrometric solutions and were used (or measured) within the same solution as the target objects (ie. same zero point reference). Be careful of possible proper motion problems (ie. don't use old plates or catalogs). You must account for proper motion effects as our astrometry routines don't compensate for proper motion. Reject any stars with large uncertainties in their coordinates.

REMEMBER THAT THESE STARS ARE BEING USED TO LOCK AND GUIDE THE TELESCOPE ON YOUR TARGET FIELD!

8.2 FIBER CABLE SELECTION

The two science cables available differ in spectral response and in aperture size. Guidelines for selecting the appropriate cable can be derived from the following discussion of each cable's advantage over the other.

8.2.1 Advantages of the Red Cable

The red cable has good spectral transmission redward of 4000 Å out to nearly 2 μm (see Figure 7).

The aperture size of 2 arc-seconds was selected for good sky suppression of the OH emission lines that dominate the sky brightness redward of about 6000 Å. In addition, since atmospheric dispersion is not as bad towards the red end of the optical spectrum, the 2 arc-second diameter should not present a significant loss of light due to this effect.

8.2.2 Advantages of the Blue Cable

The blue cable has good spectral response blueward of 7000 Å down to the atmospheric cutoff (see Figure 7).

A 3 arc-second aperture was selected to provide some compensation for atmospheric dispersion while not significantly impacting on the level of the sky contamination. The need for sky suppression is not as significant in the blue spectral region as in the redward bandpasses.

8.3 CREATING THE TARGET ASSIGNMENTS

Once you have your astrometry files in hand with sufficient sky and FOPS locations, and have selected which fiber cable to use, you can proceed with the target field assignments.

Please refer to the Assignment Manual (Hydra: A Program for Assigning Fibers) for details on making the target assignments.

8.4 SUBMITTING THE TARGET ASSIGNMENTS

8.4.1 NOAO Queue Programs

For the NOAO queue, please follow target field submission procedures as outlined in your queue observing packet.

8.4.2 Visiting Astronomer Programs

For visiting astronomers, you should bring either an ExaByte or DAT SunOS tar tape of your configuration files. The tapes will serve as a backup in case there are difficulties in establishing remote connection to your home computer for ftp access to those files.

When it is your turn to observe, using either your tar tape or ftp, copy your configuration files into the hydra/fields/ directory on Oatmeal. This is where the hydra code will search for those files when you are ready to configure the instrument.

8.5 LOGGING ONTO THE COMPUTER

Please read this section if you will be a visiting astronomer or if you plan to run the Hydra simulator. Otherwise, users of the NOAO queue can skip this section.

8.5.1 Logging Onto the Console Terminal for Oatmeal

On Oatmeal, visiting astronomers should login under 'hydra' with a password the same as the mountainwide passwords. For servicing, the login is 'fibwiyn' with a secure password.

8.5.2 Starting up the Instrument Software

In a command window, type

hydrawiyn

to start up the instrument program. To initiate the simulator, use the command **hydrasim**.

Two windows will appear.

- The HYDRA-COMMANDS window where you type in the various commands to operate the instrument.
- The HYDRA-GRAPHICS window which displays a plot of the Hydra configuration and provides some rudimentary GUI capability.

An example of the graphics window is shown in figure 15.

8.5.3 Initializing the Instrument

In the COMMANDS window there will be a series initializations and various messages. The program will ask for the temperature of the instrument. The default value in the parenthesis should be checked for validity to an accuracy of about 5-10 degrees F. This is used to compensate for thermal expansion of the stage encoders.

The program will next prompt for enabling electronic power to the racks. Answer **yes** if the racks are currently off. There is no harm in answering yes even if the racks are already powered on (though you will save a bit of time by answering **no**). There are times, however, during problems where it will be necessary to answer no when the power is already on.

After the power has been established, the program will halt until the

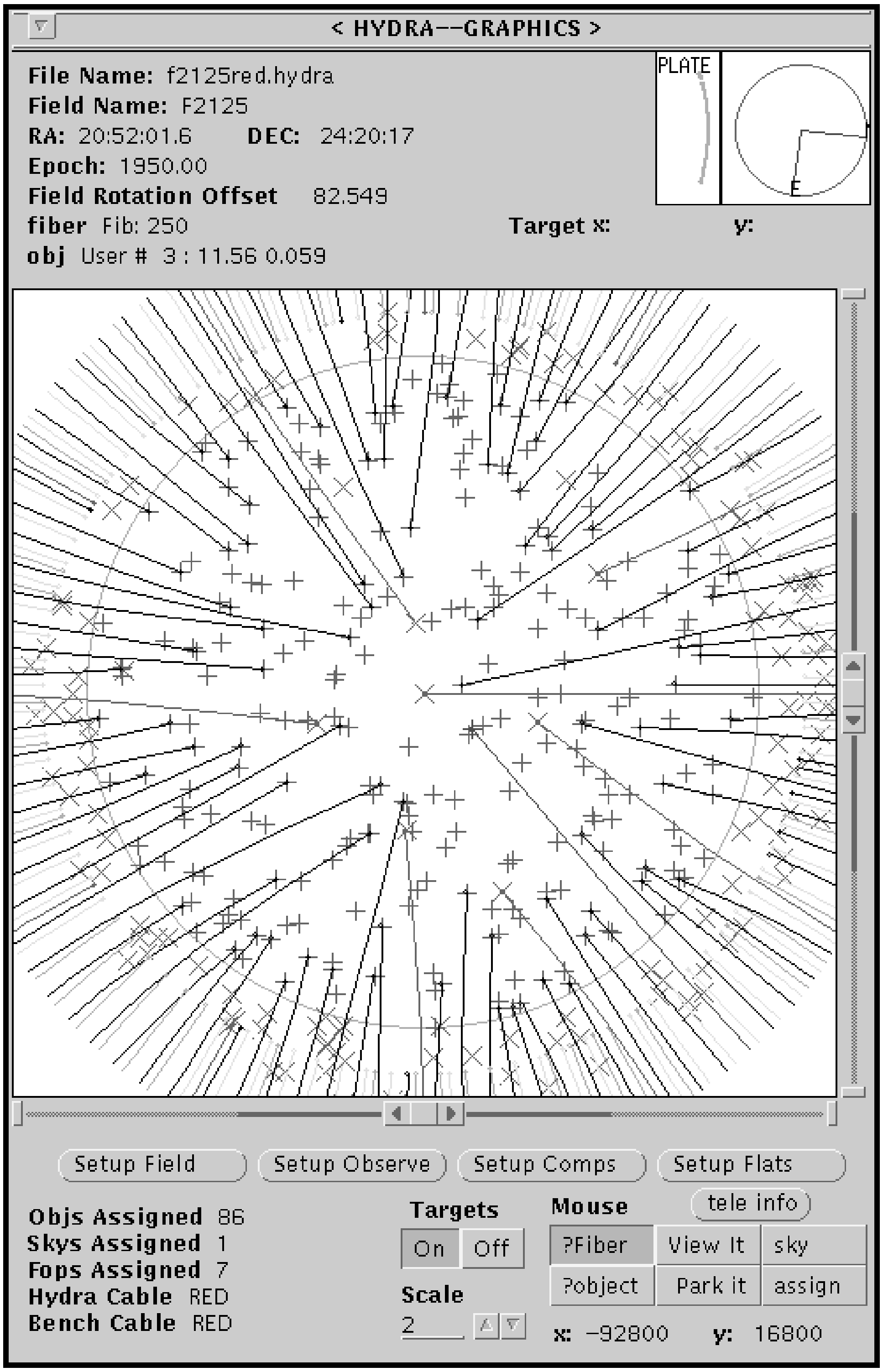

Figure 15: Sample view of Hydra graphics window.

coldstart

command has been executed. This command initializes the motors; finds the home positions for the X, Y, and Z axes; and resets the encoder counters to correspond to the center of the focal plate. It takes approximately one minute for a coldstart to complete. If the gripper camera is turned on along with the gripper LED's, you should be able to see the motion of the X and Y stages as they home.

At the end of the coldstart, the program will automatically execute a **where** and a **status** command. The first line of values should read x=0, y=0, z=0. (The motor values will be non-zero as they are recording the positional information from the motor resolvers.) The gripper should be empty.

NOTE: If there are problems, please contact trained personnel (your OT, mountain electronics, or your startup person).

After this there should be a 'Fiborg' prompt showing the current version number. If not, hit carriage return to see the prompt.

The instrument is now ready to move fibers.

8.6 CONFIGURING FIELDS

8.6.1 The Setup Field Command

In order to simplify the instrumental configuration, we have created user commands which step the astronomer through the configuration process.

The first of these configures the fibers. To execute, either type

setup field

or click on the **setup field** button in the graphics display.

You will be prompted to give the full name of the configuration file.

If the file is not designed for the currently selected fiber cable, a warning message will be given and you will have the opportunity to switch to the cable that your field is designed for. NOTE: This only changes a software flag of cable type. You must still verify that the Bench Spectrograph has the appropriate cable installed. (The cable installed on the Bench Spectrograph should be displayed in the HYDRA-GRAPHICS display.)

Next you will be given the opportunity to modify how long you plan to observe the field in this configuration and what the anticipated midpoint sidereal time will be. Both of these values will be used to fine tune the atmospheric refraction component of the astrometry. If you are rerunning a setup due to a button problem, make sure that you answer these questions in an identical manner as before or the positioner may end up tweaking each and every fiber instead of picking up where it had left off.

After this, you have the option to either park all unused fibers or leave unused fibers where they are as long as they don't interfere with fiber placement. Leaving them where they are allows such fibers to be flagged as random sky positions and also decreases the configuration overhead since the positioner doesn't have to spend time moving them.

The program will then check certain aspects of the instrument status (plate flat, comps off, rotator at zero degrees), compute the new astrometry, and proceed to move the fibers.

When all fibers have been positioned, the .iraf file will be generated and fiber information will be passed to the CCD for inclusion in the data headers.

NOTE: The instrument is not yet ready to take the observations. You MUST execute the **setup observe** command described in section 8.6.3.

8.6.2 Sample of Setup Field Command

```
Fiborg 4.0.0 >setup field
Enter name of  hydra file.
>
f2125red.hydra
#0000000011111111112222222222333333333344444444445555
#2345678901234567890123456789012345678901234567890123
Current file name : f2125red.hydra
Field name        : F2125
Equinox(IN)       :    1950.00
Current epoch     :    1995.60
Mid-exposure ST   :      21.00
Exp. Time (hr)    :       0.50
Spectrograph wavelength :    8000.00

WARNING:  File is not intended for the current fiber cable!
Would you like to switch the current cable to match [ Yes or No ]?
(Yes)> yes

How long do you plan to observe with this configuration? [hours]
(0.50)> 3

Enter the anticipated sidereal time at midpoint.
( 21:00:00.0)> 19.5

Park unused fibers [ Yes or No ]?
(Yes)>
Making sure comparison sources are off.
CU lamp set is OFF
```

```
Turning on gripper. LEDs
Flatting plate.
WAITING: --for rotator to go to zero.
Rotator is in Position.
generating interaction table.
Parking fiber 2, which means:  moving button   2 to  86217,   3765
Parking fiber 5, which means:  moving button   5 to  85786,   9396
moving button   0 to     21,    -15
moving button   1 to  56678,   2134
moving button   4 to  62543,   8663
Parking fiber 8, which means:  moving button   8 to  84988,  14987
moving button   7 to  57547,  10568
moving button  10 to   8530,   1906
moving button  13 to  65007,  21824
moving button  16 to  68778,  27071
.
.
.
moving button 262 to  57564, -42117
moving button 264 to  25712,  -6516
moving button 274 to  53972, -20405
moving button 277 to  35582,  -6634
moving button 283 to  48806,  -7698
moving button 286 to  69383,  -5806
Writing Aperture Identification file into: /home/fibdev/fields/f2125red.hydra.iraf.5
Compressing and purging archive CurrentLocations file. Please wait.
Warping the focal plane plate.
--please wait...
Fiborg 4.0.0 >
```

8.6.3 The Setup Observe Command

To set the instrument ready for observations, type

setup observe

or click on the appropriately labeled button in the graphics display.

Note that this command is only valid after a field has been configured with the **setup field** command.

The program will make sure that the plate is warped, the comp lamps are off, and that the screen is out of the way. It will then ask if you are ready to move the instrument rotator into position. After that, the gripper will move to field center for initial field acquisition. You will then be allowed to view fibers or objects with the gripper TV. (Unfortunately, you must stick with the menu driven view process as we don't yet have the graphics view control interlaced with the setup observe command.)

While viewing some fibers, it may be necessary to tweak the rotator offset angle. There is a -0.5 degree instrumental offset that must currently be manually corrected for. The OT can assist in making this adjustment. We will automatically compensate for this offset in the next version of the software.

When finished viewing and aligning on the field, the gripper will be moved to an unobstructing position and the stage motors will be disabled to minimize vibration and heat generation during the observations.

The OT should then fire up the guider which will center the FOPS stars and will optimize the rotational alignment.

8.6.4 Sample of Setup Observe Command

```
Fiborg 4.0.0 >setup observe
Making sure the focal plane plate is warped.
--please wait...
Do you wish to move the rotator into position [ Yes or No ]?
(Yes)> no
Making sure comparison sources are off.
CU lamp set is OFF
Moving to field center.
Insuring LEDs are off.
Making sure screen is out of the way.
Do you wish to view any fibers [ Yes or No ]?
(No)> y

To view buttons or objects, enter:

'o id# <return>' for an object
'f id# <return>' for a  fiber
's id# <return>' for a  slit position
'  c   <return>' for the field center
'  b   <return>' for a benign gripper position
'  ?   <return>' for this menu
```

```
Hitting <return> on an empty line will exit the loop

view> f 192
viewing button #192
This fiber, #192, is Extended
Viewing obj. #2 "10.42 0.041         "  fiber: 192 Probe I
view>
Making sure Gripper is out of the way.
WARNING:  X,Y motion is now *disabled*!
Use "gripin" to re-enable.


YOU ARE NOW READY TO BEGIN OBSERVATIONS!

Fiborg 4.0.0 >
```

8.7 WAVELENGTH CALIBRATIONS

Wavelength calibrations are made by moving a screen over the fibers and illuminating the screen with a bank of Hollow-Cathode tubes. Either Th-Ar or Cu-Ar sources are available. To switch sources, the OT must swap a connection located on the fork of the telescope underneath the instrument.

8.7.1 The Setup Comps Command

One can take wavelength calibrations by executing the command

setup comps

which, again, can either be typed or executed by clicking the appropriate button in the graphics display.

The routine will check to see if the TV's are turned off (to save them from exposure to the bright light). After that, the lamps will be turned on and the screen will be moved in. The gripper will again be moved out of the field and deactivated.

8.7.2 Sample of Setup Comps Command

```
Fiborg 4.0.0 >setup comps
```

```
Bringing in calibration screen.
Making sure gripper LED are off.
Checking Gripper and FOPS camera(s)
GRIPPER TV IS ON
Please have OT turn down high voltage on camera(s)

Are the cameras off? [ Yes or No ]?
(No)> y
Turning on comparison lamps.
Checking Gripper and FOPS camera(s)
CU lamp set is ON
Making sure gripper is out of the way.
WARNING:  X,Y motion is now *disabled*!
Use "gripin" to re-enable.

YOU MAY NOW BEGIN TAKING COMPS.

Please use "setup observe " or "complamp off" when finished.
Fiborg 4.0.0 >
```

8.8 FLAT FIELD CALIBRATIONS

There is a White Spot on the side of the WIYN dome for taking flat fields. Dome flats should be taken for each configuration of the fibers either just prior to the target observations, or soon afterwards. Both the fiber-to-fiber throughput differences and CCD pixel-to-pixel sensitivity variations can be corrected for using the white spot flat fields.

8.8.1 The Setup Flats Command

To set the instrument up for taking dome flats, either type the command

setup flats

or click the button in the graphics display.

This routine only makes sure that the instrument is in a state for flat field observation. The OT will have the responsibility of pointing the telescope at the white spot and for turning on the flat field lamps.

We have been using the bright lamps on their highest setting for all spectrograph configurations.

8.8.2 Sample of Setup Flats Command

```
Fiborg 4.0.0 >setup flats
flats
Making sure gripper LED are off.
Checking Gripper and FOPS camera(s)
Making sure comparison sources are off.
CU lamp set is OFF
Making sure screen is out of the way.
Making sure gripper is out of the way.
WARNING:  X,Y motion is now *disabled*!
Use "gripin" to re-enable.
ATTENTION:  Please have OT set to white spot and turn on lamps.

Is telescope in position with lamps on? [ Yes or No ]?
(No)> y
Fiborg 4.0.0 >
```

8.9 TELESCOPE FOCUS

The Observing Tech (OT) will generally do a Delivered Image Quality (DIQ) measurement early in the night to check and set the telescope optics. However, this does not establish the proper focus for the Hydra instrument. The telescope focus for Hydra must be done while on the target field or while viewing a star with Hydra.

Telescope focus is best done while observing stars with the FOPS, most likely after acquiring the first target field. The focus can be achieved either manually by maximizing the signal into the central fiber of a FOPS probe, or by running an autofocus routine (an OT task).

In conditions of very poor seeing (¿ 2 to 3 arc-seconds), the telescope can be focused with the Hydra Gripper TV. However, do not rely on this as a good focus for when the seeing is less than 2 arc-seconds.

8.10 AUTOGUIDING

The FOPS information is automatically transferred to the guider software (in most cases). This is an OT operation and should be fairly straightforward with good communication between the OT and the observer.

A minimum of 2 FOPS must be active in order to guide the three axes of the telescope (azimuth, altitude, and field rotation). Again, we remind you that we suggest 3 or more active FOPS in order to compensate for astrometric and fiber positioning errors.

Parked FOPS will serve as sky monitors so that the guider will know when to disable itself due to cloud interference.

8.11 OBSERVING STANDARD STARS

It is relatively easy and quick to move single fibers to the center of the field for the observation of standard stars. Unfortunately, there are a lot of details about the instrument that can easily confuse the uninitiated.

We have developed a command to handle most of the details (such as warping or unwarping the plate when needed). This command allows the observation of single stars and uses the gripper TV camera for guiding.

We have also started a list of standard stars with related hydra configuration files so that the FOPS guider may be used. This approach eliminates the need to use the gripper TV for guiding, reducing the setup overhead as a result.

8.11.1 The Standard Command

The following command can be used to place a star down any user specified fibers (specified by position along the slit).

Note, however, that this command may park some extended fibers in order to get the desired fiber positioned to field center. Rerun the **setup field** command to reconfigure the displaced fibers making sure that you keep the same values for the sidereal time and duration of the observations otherwise, all of the fibers may be slightly repositioned instead of just those that were parked.

Type

standard

to execute a procedure for putting a single star down the fiber of the currently selected cable.

You will be prompted for the slit position that you desire. A FOP will then be moved into the field center for centering and focusing the telescope on the star.

You will then search for a guide star with the gripper TV using the arrow keys in the same manner as the **cruise** command (see page 50). Note that preceding the arrow keys with a zero will cause the gripper to move in steps comparable to the TV field of view.

After that is complete, the command will park the FOP and move in the fiber corresponding to the selected slit position for the observation.

The gripper will then return to the guide star location for closed loop guiding during the observation.

8.11.2 Sample of Standard Command

```
Fiborg 4.0.0 >standard


Which slit Position do you wish to use?
( 99)> 96
Slit position #96 will use fiber #157
************************************
WAITING: --for rotator to go to zero.
Rotator is in Position.

Moving FOPS 0 to center of field.
generating interaction table.
Parking fiber 46, which means:  moving button  46 to  46367,  72785
Parking fiber 264, which means:  moving button 264 to  74738, -43148
Parking fiber 277, which means:  moving button 277 to  83827, -20510
moving button   0 to      0,      0
Warping the focal plane plate.
viewing button #0
This fiber, #0, is Extended
Viewing unassigned  fiber: 0 Probe A
Presetting and enabling the rotator.

 PLEASE HAVE THE O.T. ACQUIRE AND CENTER THE STAR (on Gripper TV).


  Is the star centered? [ Yes or No ]?
(No)> y
************************************
 Now acquire a guide star with the gripper on gripper TV.

 PLEASE HAVE THE O.T. RE-CENTER THE STAR (on FOPS TV).

--and check the focus (on FOPS TV).


  Is the star centered? [ Yes or No ]?
(No)> y
```

```
***********************************
WAITING: --for rotator to go to zero.
Rotator is in Position.
generating interaction table.
Parking fiber 0, which means:  moving button   0 to  86299,      1
Parking fiber 160, which means:  moving button 160 to -81095, -29517
Parking fiber 168, which means:  moving button 168 to -74737, -43151
moving button 157 to      0,      0
Warping the focal plane plate.
Presetting and enabling the rotator.

 PLEASE HAVE THE O.T. ACQUIRE AND CENTER THE STAR (on Gripper TV).


  Is the star still centered? [ Yes or No ]?
(Yes)>y


 YOU ARE NOW READY TO BEGIN OBSERVATIONS.

Fiborg 4.0.0 >
```

8.11.3 An Alternative to the Standard Command

There are some Hydra configuration files available for observing standard stars by the normal configuration process which places FOPS in the field of the standard for guiding. This minimizes the overhead of searching for guide stars in the **standard** command with the gripper TV. These files are located in the ~/stdfields directory of the fibwiyn account and are usable from the hydra visitor account (the program looks in this directory as well as in the fields directory for hydra configuration files).

Hydra can be configured for such files following the normal field configuration process (**setup field** and **setup observe**). Just type in the name of the file when prompted as you would your other files.

Type

ls /home/fibwiyn/stdfields

to see the list of files available in that directory.

The current list of standards available in configuration file format are:

BD+284211 in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

Feige 34 in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

Feige 66 in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

Feige 67 in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

Feige 110 in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

G191B2B in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

GD 140 in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

Hiltner 600 in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

HZ 44 in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

PG0823+546 in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

Wolf 1346 in file *fxb.bd284211.hydra* or *fxr.bd284211.hydra*

The fx indicator shows that the star is a flux standard. The fxr files are for slit position 50 of the red cable. Observations through slit position 50 of the blue cable are made by configuring the fxb files.

NOTE: We have not yet verified that these files are astrometrically viable. Please use at risk until we have had a chance to do so. It is also only possible to observe the star through slit position 50 at the current time.

We will attempt to add in some radial velocity standards as time permits. Such files will be indicated by an rvr or rvb prefix.

We suggest that the observer consider creating similar Hydra configuration files for their specific standards if possible. Caution must be exerted to ensure that such fields will be astrometrically viable.

8.12 USE OF SCRIPT FILES

8.12.1 How to Run a Script File

Script files are available for Hydra configurations and operation. A script file is a list of instrument commands that can be executed by

exec <*filename*>

There are several script files available for operation.

If you are interested in creating your own script files to do things like position unassigned fibers onto blank sky areas, please see one of the staff contacts regarding additional commands that may be useful for running those scripts.

8.12.2 Useful Script Files

Some useful script files are listed here.

bluecircle — Configures the blue fibers into a circle near the field center.

center — Moves the gripper to the plate (field) center.

parkall — Parks all of the fibers.

redcircle — Configures the red fibers into a circle near the field center.

viewblue — Views all of the blue fibers with a wait delay of 2 seconds between views.

viewfops — Views all of the Field Orientation Probes with a wait delay of 2 seconds between views.

viewred — Views all of the red fibers with a wait delay of 2 seconds between views.

8.13 EXITING AND INSTRUMENT SHUT DOWN

We strongly advise that the Hydra instrument be powered down and the program exited at the end of each night and restarted again in the afternoon.

To quit the program, type

quit

You will be prompted to power off the racks. Answer **yes** if it is the end of the night. During the night, it may be best to leave the racks powered on if the program will again be started later that night. Also, one may need to leave the power on in cases of instrument difficulty.

8.14 INSTRUMENT PROBLEM RECOVERY

Recovery from Instrument Problems should be done by a properly trained person or under the direct supervision of such a person.

8.14.1 Recovery of Lost Fibers

The button sensing of the gripper will halt the positioning routine if there is a dropped fiber or one that it couldn't pick up. In most cases, the errant fiber can easily be recovered through use of the gripper TV camera.

The following steps should be used for simple fiber recovery.

- If the fiber is not visible in the gripper TV, try to view the errant fiber with

  view <*fiber#*>

  or by clicking the **view** button in the graphics window followed by a click on the fiber in trouble in the graphics display.

- If you can see that the fiber/button is displaced from the center of the gripper, type

  cruise

  to move the gripper over the button with the H, J, K, L, or ←, ↓, ↑, → keys. Typing a 1 through 9 prior to each arrow key will scale the step size by a power of two scaling.

  Hit return when the fiber is centered in the gripper.

- The software now needs to know the corrected location of the lost fiber.

  Type

  thisis

  to update that position.

- Type

  park <*fiber#*>

  to see if the problem is cured by parking the troubled fiber.

- Rerun the setup command (or whatever action was being conducted) and all should proceed well.

If the lost fiber can not easily be found with the viewer, have trained personnel (the Observing Tech) go to the telescope and inspect the hardware. If they had to reset the lost fiber by hand, they will have placed it into its stow position. The software will have to be informed of this action with the following command.

xstowed <*fiber#*>

That fiber should then be parked with

park <*fiber#*>

before normal operation can resume.

8.14.2 X-Stage Realignment

We have, unfortunately, experienced occasional misalignment of the dual drive, X stages. Some recent modifications to the motor parameters have hopefully eliminated this problem though we do not yet know since the problem occurs fairly infrequently. Such a misalignment will become obvious by making it impossible for the instrument to pick up large numbers of fibers. If that is the case, the OT should inspect the instrument to verify that the stages are indeed misaligned and, if so, should proceed to realign them.

Such a misalignment should be reported via email to the staff contacts and support personnel.

NOTE: This operation should only be done by trained personnel.

- Execute the **gripout** command.
- Set the brake selector switch to MANUAL.
- Manually move both X stages to the hard stops (about 3 turns clockwise rotation). If possible, please note which stage is out of alignment by counting the number of turns required to bring each stage into the respective hardstop.
- Rotate the brake selector switch back to AUTO.
- Execute the **coldstart** command.
- Report the problem to the appropriate personnel with how many turns each stage took to reach the hard limit and any other information that might yield insight into the problem.

8.15 SOME MISCELLANEOUS USEFUL COMMANDS

8.15.1 Determining Location of the Gripper, Fibers, and Objects

The **where** command will give the coordinates of the gripper.

```
Fiborg 4.0.0 >where

gripper is at plate:  x =  89999  y = -89999  z =      0
                 sky:  x =  89834  y = -90165  z =      0
             encoder:  x =  89976  y = -90020
```

The default **whereis** command will give the coordinates of a fiber by its fiber number.

```
Fiborg 4.0.0 >whereis 64
object: #2226 "SKY                 "  fiber: 64 at slit pos: 30
That object is at -26315 46102
Button #64 is at x = -26394, y = 46074 which is Extended
```

The **whereis** command can also be used to find a fiber by its slit position number with the **s** flag.

```
Fiborg 4.0.0 >whereis s 38
object: #318 "A2255...... 318     "  fiber: 118 at slit pos: 38
That object is at -16898 -15674
Button #118 is at x = -16892, y = -15710 which is Extended
```

In addition, the **whereis** command will show the coordinates of an object using the **o** flag plus object number.

```
Fiborg 4.0.0 >whereis o 449
object: #449 "A2255...... 449     "  fiber: 138 at slit pos: 51
That object is at -2332 -11582
Button #138 is at x = -2295, y = -11579 which is Extended
```

8.16 THE .IRAF FILE AND CCD HEADER INFORMATION

The .iraf file is currently used to inform iraf of which spectrum corresponds to which object. The slit position is indicated by the first column of the file. The second is a flag used by IRAF to determine the type of spectrum (-1 for unused, 0 for sky, 1 for object, and 3 for random position). The third column gives the object name and references the user id number for that object (in parentheses). The decision to leave out any currently unused fibers that were used in a previous configuration causes those entries in the file to be labeled as “Random position”. They may either be used as additional skies or ignored during the data reduction process.

In the near future, iraf will no longer need the .iraf file for the object to spectrum cross-referencing as the pertinent information is now being stored into the CCD headers. The .iraf files will, however, continue to be used as a backup in case the information in the headers becomes corrupt or is missing.

8.16.1 Sample .iraf File

A sample .iraf file is shown here:

```
# Thu Aug 10 21:19:23 1995
# Hydra Filename: f2125red.hydra
# LST Middle :   19:30:00.0
  1 -1 not assigned
  2  1 10.43 0.467 (244)
  3  1 12.18 0.135 (13)
  4  1 12.28 0.466 (243)
  5  1 11.69 0.479 (253)
.
.
.
 89  1 12.55 0.320 (114)
 90  1 12.35 0.377 (149)
 91 -1 not assigned
 92  1 12.93 0.335 (120)
 93  1 11.17 0.440 (215)
 94  1 12.80 0.392 (165)
 95  1 12.25 0.389 (163)
 96  1 13.26 0.433 (207)
 97  1 11.56 0.389 (161)
 98  1 13.27 0.503 (277)
 99  1 12.41 0.354 (129)
100  1 11.50 0.312 (105)
```

A LIST OF ACRONYMS AND SOME USEFUL TERMS

Acronyms:

- ArCon – Array Controller, controls the T2KC CCD on the Bench Spectrograph.
- ATV – Acquisition TV camera on the Bench Spectrograph which views the fiber slit.
- FBI – Fiber Back Illuminator, a bank of LED's which illuminates the fiber slit for viewing fibers with the gripper camera.
- FOPS – Field Orientation Probe, a 7-fiber bundle placed on a bright star for locking the telescope pointing onto the target field. There are twelve FOPS available.
- ICCD – Intensified CCD camera. Both the gripper camera and the FOPS camera are ICCDs.
- OT – Observing Tech, either your telescope operator or the daytime mountain support person.
- SCS – Simultaneous Comparison Sources on the Bench Spectrograph.
- SSD – System Status Display. Video display of telescope and instrument status.
- T2KC – CCD used on the Bench Spectrograph.
- WIYN – Wisconsin, Indiana, Yale, NOAO consortium member of the telescope.

Some useful terms:

- fiber # – The number corresponding to the position of a fiber around the circumference of the focal plate.
- object # – The user number of a target (first column) in the .hydra file.
- slit # – The number referring to the position of a fiber along the spectrograph slit.

B LIST OF POSITIONER COMMANDS

The following is a list of most commands for operating Hydra. Those marked with a bullet are the ones most likely to be encountered by the typical observer. The graphical user interface has buttons which execute many of the most important commands.

NOTE: This list is currently INCOMPLETE.

HYDRA-COMMAND window commands:

setup commands:

- **setup field** — User level command for configuring a target field.
- **setup observe** — Readies the preconfigured instrument for observations.
- **setup comps** — Sets the instrument up for taking comparison lamps.
- **setup flats** — Sets the instrument up for taking dome flats.

Calibration lamp and screen commands:

- **screen in** — Moves the calibration screen into place for calibrations.
- **screen out** — Stows the calibration screen out of the way.
- **screen status** — Displays status information about the screen.
- **screen test** — Moves the screen to test its functionality.

miscellaneous commands:

- **coldstart** — Initializes the hardware.
- **gripout** — Moves the gripper out of the way for observations.
- **gripin** — Moves the gripper back into action.

goxy <*X*> <*Y*> — Moves the stage to the X, Y plate position in encoder values.

gox <*X*> — Moves only the X stage.

goy <*Y*> — Moves only the Y stage.

goz <*Z*> — Moves the Z stage to the given Z coordinate.

move <#> <*X*> <*Y*> — Moves the fiber at position <#> to the coordinates X and Y (restricted to valid ranges and no collisions).

park <#> — Moves fiber <#> to its park position.

status — Allows a check of the various modes and their status.

view <#> — Moves the gripper over to view the fiber at position <#>.

view o <#> — Moves the gripper over to the object with number <#>.

view s <#> — Moves the gripper over to the fiber at slit position <#>.

where — Gives the gripper coordinates.

whereis f <#> — Gives the coordinates of fiber <#>.

whereis o <#> — Gives the coordinates of object <#>.

whereis s <#> — Gives the coordinates of the fiber at slit position <#>.

xparked <#> — Updates the fiber data base to change the stored X and Y values to the position corresponding to the park position of fiber <#>.

xstowed <#> — Updates the fiber data base to change the stored X and Y values of fiber <#> to the position corresponding to the fiber's stow position. Use this command when manually restowing a misplaced fiber.

HYDRA-GRAPHICS window commands:
The following commands may be typed from either the COMMANDS Window or via the appropriate GRAPHICS window button.

setup field

setup observe

setup comps

setup flats

park

assign

view

whereis

targets on to display the target objects when a configuration field is loaded.

targets off to turn off the plotting of the targets.