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Scott D. Horner, Leland G. Engel, Lawrence W. Ramsey, "Hobby-Eberly Telescope medium-resolution spectrograph and fiber instrument feed," Proc. SPIE 3355, Optical Astronomical Instrumentation, (9 July 1998); doi: 10.1117/12.316775

Event: Astronomical Telescopes and Instrumentation, 1998, Kona, HI, United States

The Hobby-Eberly Telescope medium resolution spectrograph and fiber instrument feed

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ABSTRACT

The Medium Resolution Spectrograph (MRS) is a high throughput, versatile, fiber-fed echelle spectrograph for the Hobby-Eberly Telescope (HET). This instrument is designed for a wide range of scientific investigations; it includes single-fiber inputs for the study of point-like sources, synthetic slits of fibers for long slit spectroscopy, multi-fiber inputs for multi-object spectroscopy, and an optical fiber integral field unit. The MRS will have resolution settings between $3500 < \lambda/\Delta\lambda < 21000$ and will consist of two beams. The initial, visible wavelength beam will have wavelength coverage from 450 - 900 nm in a single exposure. This beam will also have capability in the ranges 390 - 450 and 900 - 950 nm by altering the angles of the echelle and/or cross-disperser gratings. Later, a second beam operating in the near-infrared will be added which will have coverage of 950 - 1300 nm in a single exposure and capability out to 1800 nm.

The HET Fiber Instrument Feed (FIF) is mounted at the focal plane of the telescope and positions the fibers feeding the MRS and the High Resolution Spectrograph (HRS). The unique and economical design of the FIF enables the HET's versatility in performing a wide range of scientific investigations with the telescope operating in a queue-scheduled mode.

Keywords: instrumentation: spectrographs

1. INTRODUCTION

The Hobby-Eberly Telescope (HET) marks a fundamental departure from the usual paradigm for building large optical telescopes. Central to the HET approach is specialization: the HET is tailored for spectroscopy, and in particular, fiber-coupled spectroscopy. The MRS is a key component of the planned HET instrument suite, which also includes a high throughput, low resolution ($600 < R=\lambda/\Delta\lambda < 3000$) prime focus imaging spectrograph (Hill et al. [1]), and a fiber coupled high resolution ($30000 < R < 120000$) spectrograph (Tull [2]).

Ramsey et al.[3, 4] and Sebring et al.[5, 6] describe the HET in detail. Briefly, the HET has a segmented spherical primary mirror with the central optical axis tilted at a fixed 35° angle from the zenith. The HET is thus a tilted, optical Arecibo-type telescope, but with full azimuth freedom allowing it to access declinations in the range -10° 20' to +71° 40' - about 70% of what a general purpose telescope at the same site achieves. The HET azimuth rotation is not used for tracking, but is critical for pointing and sky access. Rather than moving the telescope to compensate for Earth's rotation, the motion of an object across the sky is followed by a tracker located at the top of the telescope, which carries the spherical aberration corrector, fiber feeds, and prime focus instruments. The tracking time across the 12° focal surface ranges from 0.75 hours at the equator to 2.5 hours at the north declination limit. The spherical aberration corrector is a four-mirror system with protected silver on each surface. This system includes an atmospheric dispersion corrector optimized for the 35° zenith tilt angle of the HET. The prime focus is a corrected and baffled 4 arc-minute field. The simplicity of this design demands that large instruments, such as the MRS, be located off the telescope and therefore fiber coupled.

The Hobby-Eberly telescope is currently in the early commissioning phase. We expect limited science operations to begin in fall 1998.

2. SCIENCE REQUIREMENTS

The MRS is designed to take maximum advantage of the high efficiency optics and queue scheduled nature of the HET. Among its many science programs, the MRS will: 1) explore the broad line regions of active galactic nuclei and quasars through dense time sampled spectroscopy, 2) examine the evolution of large scale structure in the universe through measurements of quasar absorption lines, 3) detect and characterize the properties of dark matter via kinematical measurements in elliptical galaxies, and 4) measure the age and dynamical evolution of the Milky Way through kinematic studies of white dwarf stars.

Part of the SPIE Conference on Optical Astronomical Instrumentation • Kona, Hawaii • March 1998
SPIE Vol. 3355 • 0277-786X/98/$10.00

The science programs establish the technical requirements for the MRS. We summarize here the science requirements demanded by the above programs and the far larger list of programs compiled by HET collaborators:

- The MRS must provide fiber-coupled spectroscopic capability in the range $3600 < \lambda/\Delta\lambda < 20000$.
- The MRS must provide spectral coverage between 390 and 1700 nm.
- The MRS must provide the capability for excellent sky subtraction.
- The MRS must provide dimensional stability consistent with radial velocity precision < 1 km/s.
- Efficiency of >15% on the sky is a priority MRS design goal.
- The MRS must have scattered light less than 2% in the cores of fully saturated absorption lines.
- The MRS must be compatible with high operational efficiency within the HET system; any fiber or spectrograph re-configuration must take 1 minute or less.
- The MRS must have multi-object capability of ~10 objects.

3 MRS SYSTEM CONCEPT

The basic concepts and design approaches for the MRS has been discussed by Ramsey[7]. However, the implementation has evolved since that publication. The biggest change from the original MRS concept has been the wavelength ranges of the two beam system. The design described by Ramsey[7] had a blue/red beam combination where the blue beam covered 350-650nm and the red covered 580-1100 nm. Two issues have driven us to adopt a visible and near infrared (NIR) design. One of these has been the continuing development of low-noise large format NIR arrays such as the Rockwell 1024^2 *Hawaii* array. The second issue is the desire to utilize the HET where it performs the best. Using protected silver coating throughout enhances the overall throughput of the HET. However, this also leads to lower performance in the blue. The total telescope transmission to the focal plane is given in Figure 1. This includes all geometrical, reflection and transmission losses (Ramsey et al.[4]). As can be seen in Figure 1, the total throughput falls below 50% at about 430 nm. When the blue transmission losses of an optical fibers are added (see Section 3.1.3), a compelling case is made to concentrate on the visible spectrum at wavelengths longward of 430 nm.

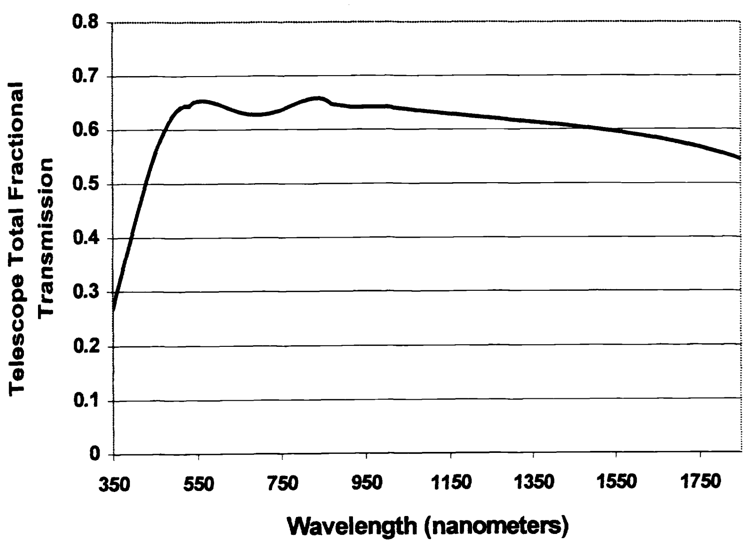

Figure 1. HET total transmission

The MRS system is comprised of three major subsystems: 1) the Fiber Instrument Feed, 2) the MRS visible wavelength beam, and 3) the MRS near infrared (NIR) beam. The Fiber Instrument Feed (FIF) subsystem interfaces directly with the telescope at the prime focus of the HET spherical aberration corrector. The MRS and HRS spectrographs are located in climate-controlled rooms below the telescope room, with nearly 200 optical fibers feeding light from the FIF to the two spectrographs. The FIF includes the fiber positioners, control electronics, and fiber optic cables to the spectrograph rooms. The other two subsystems of the MRS spectrograph system are the two beams of the dual beam spectrograph. Each beam has a cross-dispersed echelle in a white pupil configuration with separate cameras and detectors.

3.1 The Fiber Instrument Feed

3.1.1 Design

The FIF sits at the prime-focus of the HET. Mounted on the tracker, the FIF is moved along the curved focal surface of the telescope by the tracker to track target objects as the Earth rotates. The tracker also rotates the FIF to remove field rotation. The FIF is then responsible for positioning the required optical fibers in the 4 arc-minute science field-of-view (FoV), which is 2 inches in diameter.

Due to its inaccessible location on the telescope and the queue-scheduled operation of the HET, the FIF must automatically position a variety of optical fibers quickly and accurately. The FIF is also located on a moving platform - the tracker - and sits within the central obstruction of the telescope system, so it must also be lightweight and have a small profile. With these requirements, as well as cost constraints and the small physical size of the FoV, we designed the FIF using the one-probe, one-robot design (a.k.a. "the fishermen around the pond" design, Hill et al.[8]) rather than the one-robot, many-probe design used for many other systems such as Hydra[9].

The FIF has twelve fiber probes, two of which can translate in one dimension and ten which can translate in two dimensions. The two one-dimensional probes support the fibers for single-object observations and will be used primarily at the center of the FoV. These include the synthetic slits, integral field unit, and single object fibers, including the single object fibers feeding the HRS.

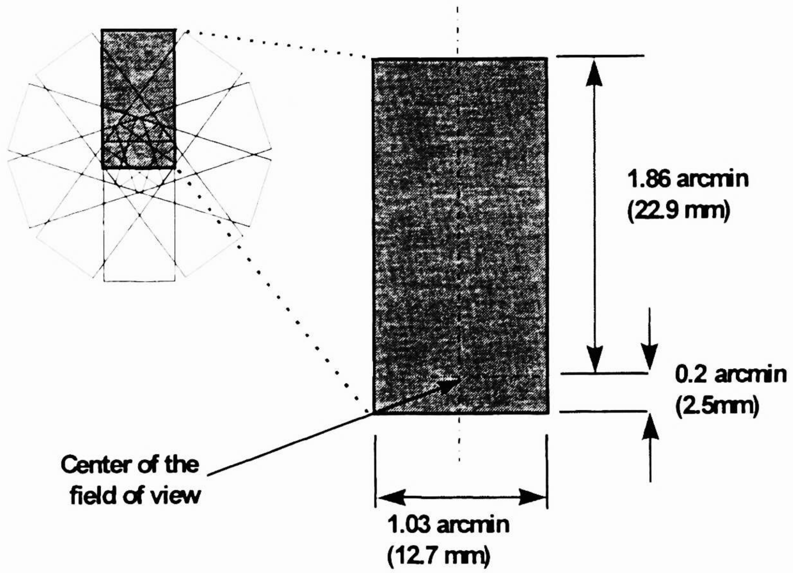

Figure 2. The field coverage of the ten MOS probes. Each probe covers 17% of the FIF field-of-view, and is equipped with three different sized pairs (object and sky-subtraction) of optical fibers.

The ten two-dimensional probes support the multi-object spectroscopy fibers for the MRS. These probes are distributed around the FoV separated by 36° to one another, as shown in Figure 2. Each MOS probe covers 17% of the FoV, with all the probes able to cover the central region of the FoV.

The probes are mounted on single (for one-dimensional probes) or crossed (for two-dimensional probes) translation stages. These stages are standard Newport Corporation low profile crossed-roller bearing translation stages, actuated by encoder-micrometers from DynaOptic Motion, and controlled using Programmable Multi-Axis Controllers (PMACs) from Delta Tau Data Systems. The use of these off-the-shelf parts makes the FIF easy to maintain and helps control costs. The PMACs are used throughout the HET control systems, so the HET operations staff is experienced in their software development and operation. This system should meet the requirement of positioning the fibers to better than 0.05 arc-seconds (10 μm).

Probe #	Probe Description	Fiber Description	Number of fibers	Fiber Size
1	one-dimensional translation probe	1.5 arc-second slit	17	300μm
		2.0 arc-second slit	13	400μm
		3.0 arc-second slit	9	600μm
		Integral Field Unit	45	200μm
2	one-dimensional translation probe	HRS fibers	13	200 - 600μm
		MRS Sliced fiber and MRS single object fibers	4	200 - 600μm
		Auxiliary fibers	6	200 - 600μm
3 & 4	Type 0 MOS probes	1.5 arc-second MOS fibers (object and sky)	2	300μm
		2.0 arc-second MOS fibers	2	400μm
		3.0 arc-second MOS fibers	2	600μm
4 - 11	Type 1 MOS probes	1.5 arc-second MOS fibers	2	300μm
		2.0 arc-second MOS fibers	2	400μm
		3.0 arc-second MOS fibers	2	600μm
12	Type 1 MOS probe	1.5 arc-second MOS fibers	2	300μm
		2.0 arc-second MOS fibers	2	400μm
		3.0 arc-second MOS fibers	2	600μm
		IFU sky fibers	6	200μm
	Total		*173*	

Table 1: A list of the probes and optical fibers in the FIF. All the fibers feed into the MRS except those indicated as HRS or auxiliary.

3.1.2 Telecentric Angle

A significant design challenge for the FIF MOS system is the telecentric angle variation of 1.6° between the center of the HET FoV and the edge. The telecentric angle is illustrated in Figure 3. If a fiber is mounted normal to the focal plane, the telecentric angle at the edge of the FoV would result in a faster output beam than the input beam; the azimuthal scrambling of the fiber will produce an output beam that is a combination of the input beam f/# plus the telecentric angle. To resolve this issue, we have increased the speed of the MRS collimator to f/4.2 and have designated two types of MOS probes. Type 0 MOS probes, of which there will be two, will have fibers mounted normal to the HET focal plane; these probes will be the preferred fibers to use for objects near the center of the FoV. Type 1 MOS probes, of which there will be eight, will have fibers mounted 1° to the normal of the focal plane; these probes will be the preferred fibers to use outside the central region of the FoV.

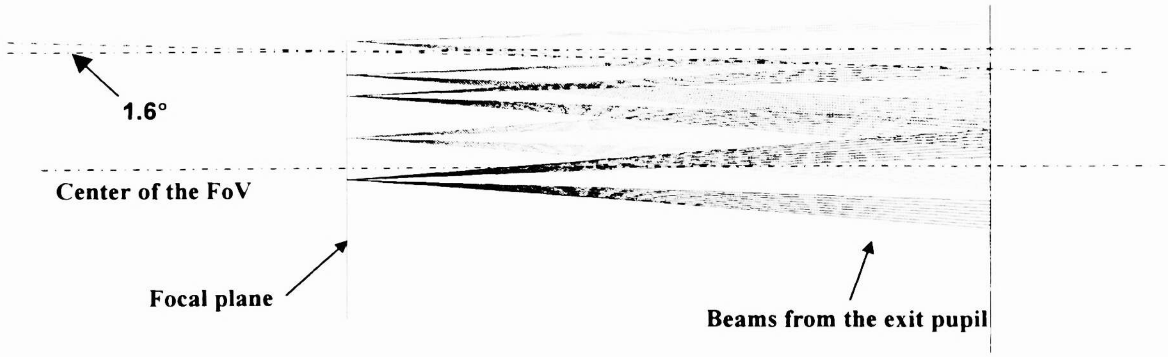

Figure 3. The telecentric variation in the HET focal plane. At the edge of the science field-of-view the telecentric angle is 1.6 ° from the normal to the focal plane. The corrected focal surface is flat over the 4 arcminute science field.

We should point out that all of the MOS probes can be used over their entire range shown in Figure 2, it is just that Type 0 probes will be more efficient (less light will be lost overfilling the collimator) in the central region of the FoV than Type 1 probes, and visa-versa (see Figure 4). The FIF is on a platform that rotates 230°, so the probe allocation can be determined by the observer to best optimize the efficiency of the system. The synthetic slits, integral field unit, and single object fibers are mounted normal to the focal plane since they will primarily be used at the center of the FoV.

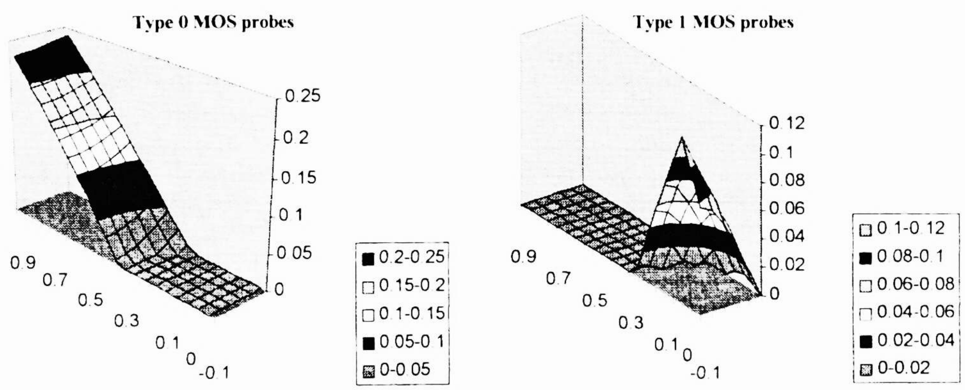

Figure 4. The figure on the left shows the loss due to the telecentric angle for Type 0 MOS probes as a function of position, where 0 indicates the center of the FoV. These fibers are normal to the focal plane and thus are optimized to be used in the central core of the FoV. The right is a similar figure for the Type 1 MOS probes, which are mounted at a 1° angle from the norm of the focal plane, and are optimized for use outside the central core of the FoV.

3.1.3 The optical fibers

The broad spectral coverage of the MRS place stringent demands on the optical fibers. We must utilize fibers that have good transmission from blue end of the visible to the NIR. Previously one selected high OH fibers to optimize transmission in the blue and low OH fiber for the red and NIR. Recently, Heraeus Amersil (Lu, Schötz and Fabricant[10]) has made available new fiber preforms than have an excellent balance of visible and NIR properties. In Figure 5 we show the transmission, including Fresnel reflection losses at both ends, for one of these fibers in the 33 meter length required for the

MRS. We have included the nominal atmospheric transmission at the HET site for a 35° zenith angle. With the exception of some of excess absorption in the J band, fibers made from this material appear appropriate for the MRS.

There is one other important consideration that the NIR beam places on the fiber specification. To minimize transmission losses, the cladding thickness must be on the order of 10 times the maximum guided wavelength (Lu, Schötz and Fabricant[10]). The NIR beam is specified to work out to 1.8 μm which means that the minimum cladding thickness must be 18 μm. This implies that all 200 and 300 μm fibers must utilize the standard 1.2 cladding/core ratio. The 400 μm and 600 μm fibers can be standard 1.1 cladding to core ratios.

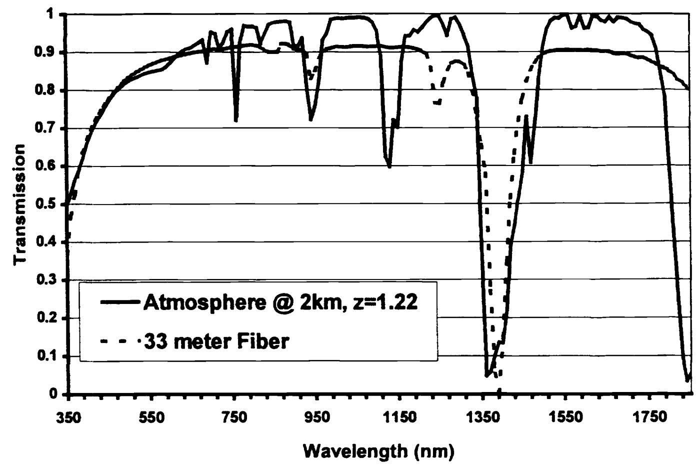

Figure 5. Fiber and atmospheric transmission

3.2 The MRS Spectrographs

The dual visible and near infrared (NIR) spectrographs are mounted on an optical bench in an environmentally controlled light-tight room under the telescope. The basic cross-beam geometry of the two white pupil spectrographs is illustrated in Figure 6. A common collimator and slit system is used to allow spectra to be obtained in both beams simultaneously. A beamsplitter is mounted in the collimated beam. The visible beam is reflected at a 45° angle by a beamsplitter that transmits at $\lambda > 950$ nm. Both the visible and NIR spectrographs employ echelle gratings and grating cross-dispersers.

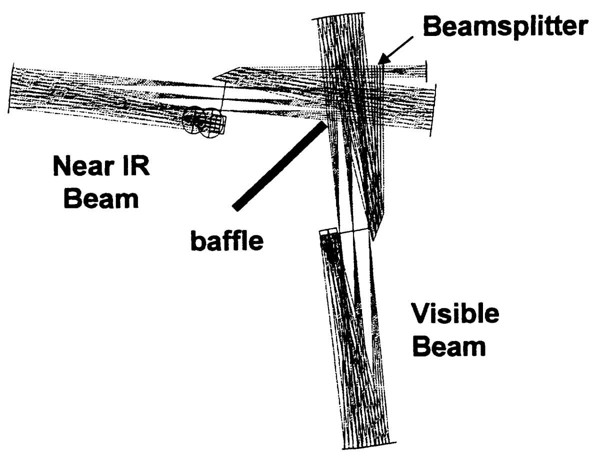

Figure 6. Cross beam geometry of MRS

3.2.1 Slit & Collimator System

As the MRS is a fiber feed instrument, detailed information on the telescope pupil is lost by scrambling and focal ratio degradation (FRD). This is seen as an advantage for the HET as the pupil shape is highly variable due to the basic nature of the HET - as the tracker moves, the telescope aperture changes size and shape (see Booth et al.[11], Hill et al.[1]). The maximum native f/# of the HET is f/4.6. To account for FRD and the variable telecentric angel in the focal plane, the collimator must have an effective focal ratio for each fiber of f/4.2 as describe in section 3.1.2. We also wish to place a pupil on the grating. This is complicated by the fact that there is a requirement to be able to select from a variety of fiber inputs. Indeed, we must accommodate all the fibers in Table 1 except those for the HRS and the auxiliary fibers. The collimator field requirement is defined by the 13.71 mm total "slit" height defined by the twenty 600 micron MOS fibers.

The MRS input slit system must be configured to work with both the visible and NIR beams. It must selectively place in the focal plane of the collimator one of nine options. There are three fibers sizes each for the long slit and MOS probes yielding a total of six options. A fiber slicer, single object fibers and an integrated field unit bring the total to nine. For the long slit and MOS options, each with three fiber size selections, the input slit system must have a 400, 300, 200 or 100 μm slit placed within 10 μm of fiber the output. This design for the slit system has each fiber input, for example the 200 mm MOS, input centered on narrow (6mm wide) but deep fiber holder. Two slit jaws positioned by precision piezo-electric actuators are about 1.5 mm thick for stiffness. This system is currently in the concept stage but the baseline design is a rotary mechanism to sequentially move the selected fibers behind the slit. The slit system allows for the following resolution options:

- R= ($\lambda/\Delta\lambda$)= 3388 with 3 arc-sec fiber (resel = 13.38 pixels un-binned)
- R= 5081 with 2 arc-sec fiber or 3 arc-sec fiber with 400 μm slit (resel = 8.92 pixels un-binned)
- R= 6352 with 1.5 arc-sec fiber or 2 or 3 arc-sec fiber with 300 μm slit (resel = 7.6 pixels un-binned)
- R= 10163 with 2 or 1.5 arc-sec fiber with 200 μm slit (resel = 4.46 pixels un-binned)
- R= 20325 with 1.5 arc-sec fiber with fiber slicer or 100 μm (resel = 2.23 pixels un-binned).

Resel is a resolution element defined by the fiber image on the CCD. Clearly, for all but the highest resolutions on-chip binning will be advantageous.

The collimator optics is shared by both the visible and NIR beams and begins with a bi-concave fused silica field lens 3 mm from the fiber surface. This lens places a pupil on the grating and is required, as all the input fibers are parallel. The parallel fibers have the same effect as placing the telescope entrance pupil at infinity. A minimum distance of 3 mm between the fibers and the field lens is needed to accommodate the slit mechanism. To minimize obstruction this lens will consist of a 10 mm wide central slice of a 15 mm diameter circular lens. About 415 mm from the concave vertex of the fused silica lens we have the vertex of the collimator mirror. The baseline design is a ~170 mm diameter asphere with a conic constant of -0.4703 and radius of 838.903. This two element basically achromatic system places a pupil on the grating 1911 mm in front of the ellipsoidal element. Figure 7 show illustrates the collimator/slit system.

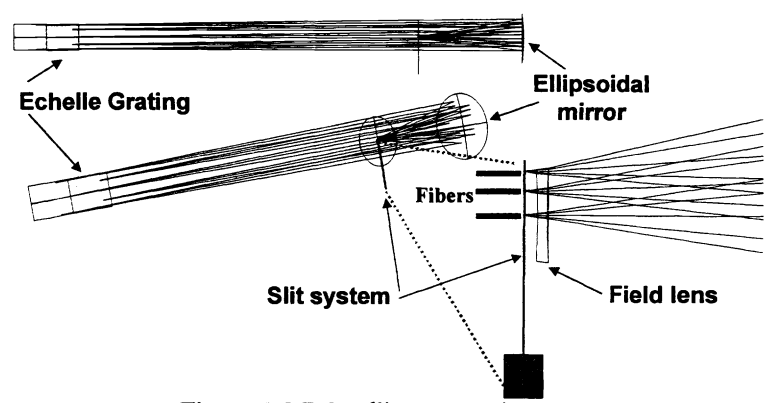

Figure 7. MRS collimator & slit system

3.2.2 Visible Beam

The visible beam will be the first to be implemented and its design is well advanced. It is configured to yield full spectral coverage in the range from 450 to 900 nm. The system is also designed to allow extended coverage down to 390 nm and up to 950 nm with different cross-disperser settings. The visible beam begins after the beamsplitter where the collimator places a pupil on a Spectronics 79 l/mm R2 (Θ_{blaze} = 63.5°) echelle grating. The ruled area is 102 x 280 mm. This gives us a 100 mm diameter beam with no vignetting at the grating. Order 25 has a central wavelength of 902 nm and a free spectral range (FSR) from 884 to 920 nm and has the largest angular dispersion within the baseline 450-900 nm range. This drives the size of the pupil mirrors and spacing of nearly all elements. For example, the position of the collimator is determined by the distance between the beamsplitter and the echelle that is required not to vignette the dispersed beam over 1 FSR in order 25. Figure 8 shows the visible beam layout viewed normal to the primary dispersion and at 90°.

The collimated beam is incident on the echelle at an angle of 68.43° (α). The θ angle is 5° so the diffraction order center diffraction angle is 58.34° (β). Thus the order center anamorphic magnification at order center is 1.42. This, of course, varies across an order and this variation is maximum in order 25. The system is out of Littrow but is in plane ($\gamma = 0$). This is only strictly true at slit center. The effective γ varies along the slit and reaches a maximum value of γ = +/- 0.9°.

Central to the MRS design are the two parabolic pupil transfer mirrors. These mirrors re-image the pupil that is on the echelle grating onto the cross-disperser (XD). This is the so-called white pupil design. This could also be accomplished with a single large spherical mirror that has the both the echelle and XD grating at opposite sides of the radius of curvature but the current system is more compact and has no spherical or comatic aberrations. Both pupil mirrors are identical 2000 mm focal length parabolas and are aligned axially so their foci coincide midway between them (See Figure 8). The center of the echelle is displaced 235 mm from this centerline on one side and the cross disperser is displaced the identical amount on the other side. Thus axial distance from the echelle center to the first pupil mirror vertex is 2013.76 mm. The shape of this mirror can be rectangular with a minimum width of ~150 mm and a minimum parent parabola diameter of 940 mm. The second pupil transfer mirror is identical and they both can and should come from the same parent parabola. Centered at the focus between the pupil mirrors is a baffle with a height of 130 mm and a width of 336 mm. This will control scattered light.

Located 2013.76 mm from the vertex of the second transfer mirror and offset 235 mm from it is the cross disperser grating. The baseline grating here is a 316 l/mm grating with a blaze of 6.8°. It is used in plane (γ=0) with a θ = 20° so the camera clears the incident beam. Due to the angle of this grating and the echelle, the pupil is not flat on the grating surface. Also, the variable anamorphic magnification of the different wavelengths lead to slightly different pupil shapes, shorter wavelengths being more elliptical. For no vignetting in order 25 the pupil size projected on the XD is 162.5 x124.5 mm.

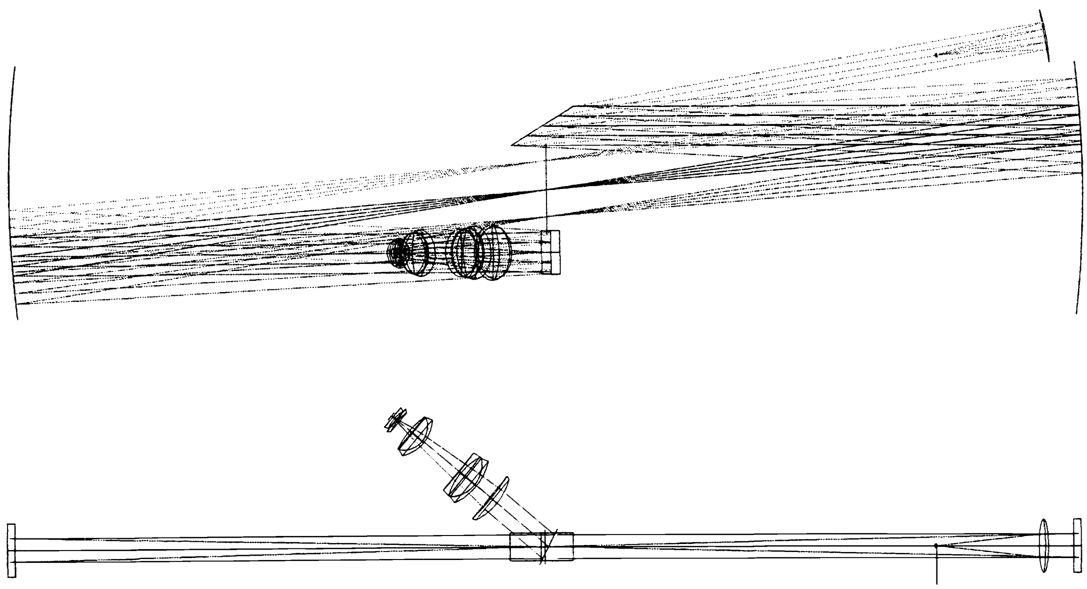

Figure 8. At the top is the visible beam as viewed normal to the plane of echelle dispersion with three wavelengths in order 25 illustrated. The bottom is a 90° view to show the orientation of the cross-disperser grating and camera more clearly.

Dr. Harland Epps designed the visible camera. The baseline design is an 8 element all refracting system and is illustrated in Figure 8. It has a 320 mm focal length and a 197 mm entrance aperture with a 78 mm field of view. This f/1.63 system has a 127 x157 mm elliptical entrance pupil is at a distance of 254 mm from the vertex of the first element. It produces an average rms. image diameter of 13.1 +/- 4.6 µm averaged over all field angles within the 390 to 1000 nm design passband. This image quality is obtained without refocus.

The CCDs, visible camera and 316 l/mm 6.8° blaze cross disperser grating combine to provides full spectral coverage on the chips from 450-900 nm when used with any of the single fibers or fiber slicer. The spectral coverage on the base line mosaic of two SITe 4096 x 2048 CCDs is illustrated in Figure 9. The horizontal line in this figure illustrates the chip butting region. By rotating the CCD so the central order is roughly parallel with the CCD, it should be possible to only have one order disrupted by the butting region. In a single fiber mode it is possible to have no losses due to the CCD mosaic. To allow clean order separation when the long slits, MOS probes or IFU are used, a higher dispersion cross disperser must be employed. A 600 l/mm 11.7° blaze grating will adequately separate

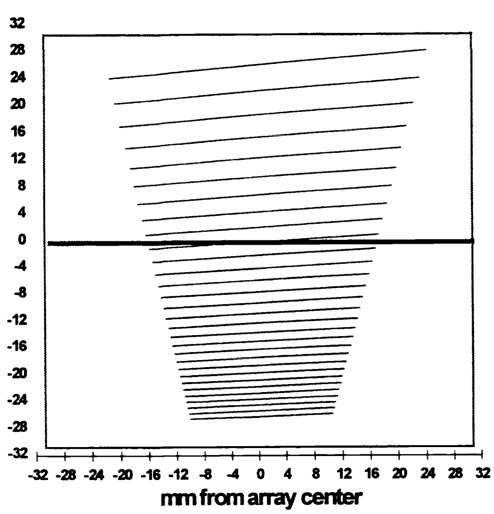

Figure 9. Format of visible beam spectrum on CCDs. Only one free spectral range is shown for each order.

all orders in the 450 to 900 nm range but will only cover about 65% of that range. The visible beam will therefore have a selection of two cross dispersers and the 316 l/mm 6.8° blaze and 600 l/mm 11.7° blaze gratings form the baseline.

3.2.3 Near Infrared Beam

The NIR system is system is in an earlier stage of development but will be similar in layout to the visible beam. However, the two beams do differ in detail. We will utilize a Spectronics 31.6 l/mm R2 (Θ_{blaze} = 63.5°) echelle grating with a ruled area of 102 x 280 mm. The geometry of the pupil mirrors is identical. The NIR system utilizes a Rockwell 1024^2 HgCdTe array with a format that will allow near complete spectral coverage from 900 to 1300 nm in a single exposure when used with a 300 mm fl camera and a 150 l/mm 5.4° blaze grating. Figure 10 illustrates the coverage on the detector. As with the visible beam, this only allows adequate order separation with single fibers and the fiber slicer. A higher dispersion cross dispersing grating has yet to be selected for the long slit and MOS fibers.

The NIR system will operate out to 1.8 μm but it will not have full spectral coverage utilizing the 1024^2 array. The camera, however, will be designed for 40 mm field of view to accommodate an upgrade to a large NIR array when they become available and funding can be identified. It should be noted, however, the NIR beam will be operated at ambient temperature, which will lead to a high thermal background through most of the H band.

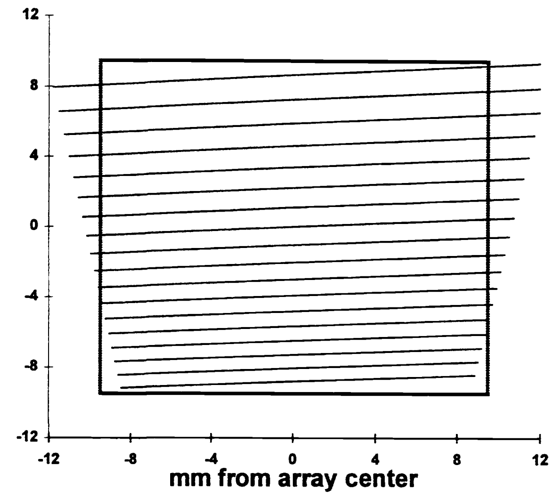

Figure 10. Spectrum from 950-1350 nm on 1024^2 Rockwell array

3.2.4 MRS throughput

The amount of light delivered to the fibers in the HET is a combination of the telescope transmission given in Figure 1

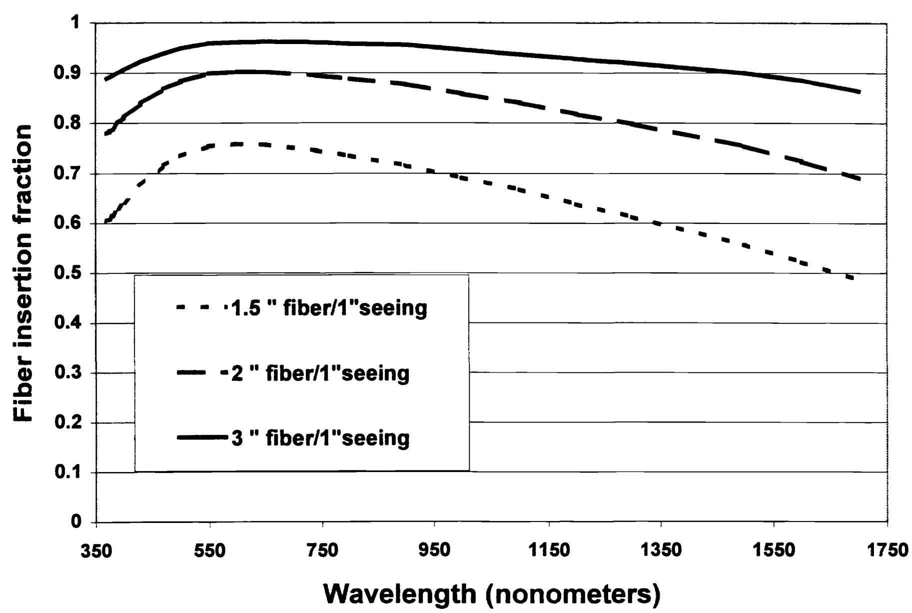

Figure 11. Fiber insertion loss as a function of wavelength.

and the transmission of the atmosphere. In addition, there is small amount of atmospheric dispersion that is not corrected. This lead to a wavelength dependant amount of light entering the circular aperture of the fiber. This fiber insertion fraction is illustrated in Figure 11 for the three sizes of fibers used on the MRS. In all cases a 1 arc-second Gaussian seeing disk is assumed. We have also assumed that the guide system centers the target at 600 nm.

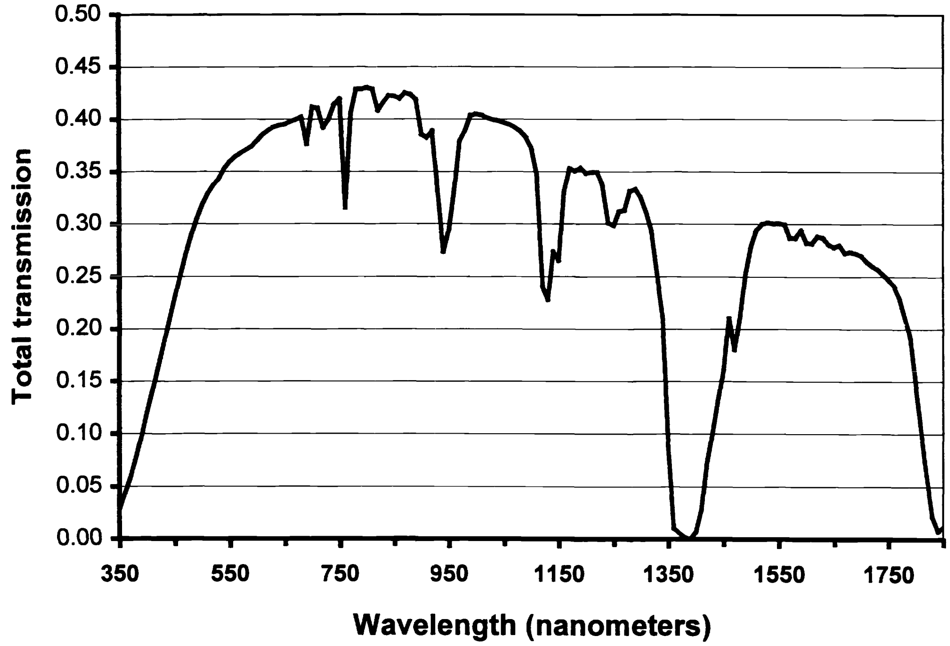

Figure 12. Faction of light from target delivered to the MRS with a 1.5 arc-second fiber in 1 arc-second seeing.

Figure 12 shows to total system fraction of light incident on the atmosphere that is output by a FIF fiber into a f/4.2 beam for a 1.5 arc-second fiber in 1 arc-second seeing. This includes the atmosphere, telescope and wavelength dependent fiber insertion losses. The visible beam is expected to have efficiency on the order of 36% at the blaze peaks. With the input efficiency to the MRS illustrated in Figure 12, we expect a peak efficiency on the order of 19% at the echelle blaze peaks.

4 MRS STATUS

The MRS will be implemented in phases. The Fiber Instrument Feed will be installed first followed by the MRS visible beam. Last will be the NIR beam in the second half of 1999. The below is a summary of the current schedule:

- Fiber instrument feed
  - Structure — May 1998
  - Probes & Probe control system — October 1998
  - Fiber cables — September 1998
- Slit system — December 1998
- Visible beam
  - Mainframe — January 1999
  - Visible camera — March 1999
  - Visible detector — November 1998
- Control system — November 1998
- NIR beam
  - Mainframe — May 1999
  - NIR camera — August 1999
  - NIR detector — July 1999
- Control system — July 1999
- Calibration system — February 1999
- Enclosure & utilities — October 1998

5 ACKNOWLEDGMENTS

Construction of the HET Medium-Resolution Spectrograph is supported by NSF grant AST9420645 and Pennsylvania State University matching funds and this support is gratefully acknowledged. We would also like to thank Robert E. Eberly of Pennsylvania and Lt. Governor William P. Hobby of Texas and other contributors that have made the Hobby-Eberly Telescope possible. We also acknowledge Dr. Robin Ciardullo for his supporting analysis of the ADC effects on the fiber transmission. Enlightening discussions with Sam Barden, John Booth, Mark Cornell, Harland Epps, John Glaspey, Victor Krabbendam, Gary Hill, Phillip MacQueen, Rob Robinson, Tom Sebring and Bob Tull have all contributed to this project.

6 REFERENCES

1. Hill, G.J., Nicklas, H., MacQueen, P.J., Tejada , C., Cobos, F.J., and Mitsch, W , 1998, "The Hobby-Eberly telescope Low Resolution Spectrograph", S.P.I.E. Vol. **3352**, *Advanced Technology Optical/IR telescopes VI*, (in press).
2. Tull, R.G , 1998, "High resolution fiber coupled spectrograph of the Hobby-Eberly Telescope", S.P.I.E. Vol. **3352**, *Advanced Technology Optical/IR telescopes VI*, (in press).
3. Ramsey, L.W., Sebring, T.A., & Sneden, C., 1994, "The Spectroscopic Survey Telescope Project", S.P.I.E. Vol. **2199**, *Advanced Technology Optical Telescopes V*, p. 31.
4. Ramsey, L.W., Adams, M.T., Barnes, T.G., Booth, J.A., Cornell, M.E., Gaffney, N.I., Glaspey, J.W., Good, J.M., Fowler, J.R., Kelton, P.W., Krabbendam, V.L., Long, L., Ray, F.B., Ricklefs, R.L., Sage, J., Sebring, T.A., and Steiner, M., 1998, "Early Performance and present status of the Hobby-Eberly Telescope", S.P.I.E. Vol. **3352-06**, *Advanced Technology Optical/IR telescopes VI*, (in press).
5. Sebring, T.A., Booth, J.A., Good, J.M., Krabbendam, V.L., and Ray, F.B., 1994, "Design and Status of the Spectroscopic Survey Telescope", S.P.I.E. **Vol. 2199**, *Advanced Technology Optical Telescopes V*, p. 565.
6. Sebring, T.A. and Ramsey, L.W. 1997, "The Hobby-Eberly Telescope: A progress report", S.P.I.E. Vol. **2871**, *Optical Telescopes of Today and Tomorrow*, p. 32.
7. Ramsey, L. W., 1995 "Hobby-Eberly telescope medium resolution spectrograph", S.P.I.E. Vol. **2476**, *Fiber Optics in Astronomical Applications*, p.20.
8. Hill, J.M., Angel, J.R.P., Scott, J.S., Lindley, D., and Hintzen, P. 1982, "Multiple Object Fiber Systems", S.P.I.E. Vol **331**, *Instrumentation in Astronomy IV*, p.279.
9. Barden, S.C. and Armandroff, T. 1995, "Performance of the WIYN fiber-fed MOS system: Hyrdra," S.P.I.E. Vol. **2476**, *Fiber Optics in Astronomical Applications*, p.56.
10. Lu, G., Schötz, G.F., and Fabricant, D. 1998, "New silicafiber for broadband spectroscopy", ASP *Fiber Optics in Astronomy III*, (in press)
11. Booth, J.A., Ray, F.B., and Porter, D.S., 1998 "Development of a star tracker for the Hobby-Eberly Telescope", S.P.I.E. Vol. **3351-20**, *Telescope Control Systems III*, (in press).