GEMINI
8-M Telescopes Project

TN-I-G0021

Fiber Evaluation for Gemini Design Parameters

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1. Overall Description

The results of tests on a 25 meter length sample of 310 micron core UV fiber are presented here. The tests covered spectral throughput, focal ratio degradation (FRD) for input f/ratios of interest, and radial scrambling of the input image as a function of input f/ratio.

2. Test Cable

The sample fiber tested is a UV transmitting silica fiber from Polymicro Technologies (FVP310372402) with a core size of 310 microns in diameter. The length of the fiber is 25 meters matching the length of the cables used with the Hydra instrument for the KPNO 4 meter. Cabling was done similarly to the Hydra cables. The fiber is sleeved with a 15 gauge Teflon tubing over the majority of its length. The ends are epoxied into steel hypodermic tubing with Epotek 353ND epoxy cured at room temperature. The hypodermic tubing is attached to 22 gauge Teflon tubing which is loosely inserted into the ends of the 15 gauge tubing (i.e. the fiber optic strand determines the physical length of the cable, not the tubing).

The ends were prepared in the same manner as the Hydra fibers with polishing carried out on a mechanical polisher down to a grit size of 0.3 microns. The tests presented here are without a prism attached to the input end of the fiber. Both the FRD and radial scrambling tests were conducted with the fiber essentially uncoiled. The transmission scan was obtained with the fiber in a coil of roughly 10 inches in radius.

A second cable was also constructed in its own tubing as a check on test results.

3. Spectral Transmission

Figure 1 shows the spectral transmission (including end losses) of the fiber from 3200 to 1.16 microns. Lamp output flux limited spectral coverage blueward of 3200Å. The red cutoff is set by the sensitivity loss of the red enhanced photomultiplier tube used to cover the region redward of 6000 Å.

OH absorption is significant in the red region. Extrapolation of the curve suggests 50% transmission at 3000 Å.

4. Focal Ratio Degradation

The focal ratio degradation (FRD) measurements were made by imaging the far field pattern of the fiber output onto a CCD video camera. The equivalent input beam cross section was also imaged for comparison. Figure 2 gives the relative amount of light exiting the fiber within the same solid angle as defined by the input cone. The 90% point corresponds to an input f/ratio of roughly f/6.3. An input cone of f/7.8 provides 80% of the output light within an f/7.8 beam.

Curves showing the relative amount of output light at various f/ratios for a given input cone are presented in Figure 3. The cases for input cones of f/4, f/5, f/6, f/7, and f/8 are shown.

Equivalent data were also obtained for f/3, f/3.5, f/10, and f/16 input beams. An example from the plot shows that 95% of an f/7 input beam is contained within an f/6 output cone.

The data shown in Figure 2 and Figure 3 were derived in different ways from the same data set. Comparison between the two figures will show slight differences which reflect the uncertainty in the absolute value of these plots caused by diffraction effects which make the aperture boundaries uncertain.

NOTE that the value determined by these plots must be multiplied by the transmission curve shown in Figure I for an estimate of the absolute throughput of the fiber (excluding seeing image quality effects).

From the given figures, it is obvious that one would like to have input f/ratios faster than f/6 to keep FRD losses below 10% for collimators matched to the telescope f/ratio (to preserve the spectrograph étendue or resolution throughput product).

5. Radial Scrambling Tests

Sky subtraction, radial velocities, velocity dispersions, and the achievement of very high signal to noise ratios all rely on excellent flat fielding. One aspect of good flat fielding is the way that the object and flat field illuminate the detector pixels. Although CCD pixels are currently quite uniform across the CCD, there are still a few percent variations between the sensitivity levels of each pixel. Such can also be true between different areas on a single pixel. To achieve the best in flat fielding stability, the CCD pixels must be illuminated in precisely the same way between the object and the flat field. Since it is the output end of the fiber that is imaged onto the detector (assuming no major optical aberrations in the spectrograph), the level to which the fiber is insensitive to image motion on the input end is important.

A point source imaged onto a fiber has its packets of light rays scrambled both azimuthally and radially about the center axis of the fiber. Azimuthal scrambling of the image is essentially perfect in even short (1 meter) fibers of modest core diameter. The amount of radial scrambling, however, is a function of the input f/ratio. Fast f/ratios tend to have a fraction of their light preserve the radial position of the image with respect to the fiber center. In such cases, image motion, or imperfect placement of a fiber onto the object, can lead to detector pixel illumination differences between the object and a uniform flat field source.

The output end of the test fiber was imaged onto the CCD video camera with a 20 power microscope objective. One set of images were obtained with a 30 micron spot imaged onto the center of the fiber. A second set was taken with the spot placed near the edge of the input end of the fiber. The input f/ratio was varied between f/2.5 and f/8 for both sets of images.

The amount of unscrambled light was estimated by subtracting the edge image from the centered image and summing the absolute values of the residuals. Figure 4 shows the images with the left column giving those with the spot centered onto the input face of the fiber. The second column shows the output image for the spot located near the edge of the fiber. In the third column are the subtracted images and the absolute values of the subtracted images are shown in the right column. The images have been contrast enhanced and zero off-set to improve the visualization of the image differences. Figure 5 presents a graph of the radial scrambling efficiency as a function of input f/ratio.

Inspection of the data show that perfect scrambling occurs for f/ratios slower than f/5. An f/3 input ratio has 25% of the image retaining the radial position of the object as it lies on the input of the fiber. NOTE that the estimate of the unscrambled fraction is a lower limit since overlapping unscrambled light between the center and edge images will cancel in the subtracted image.

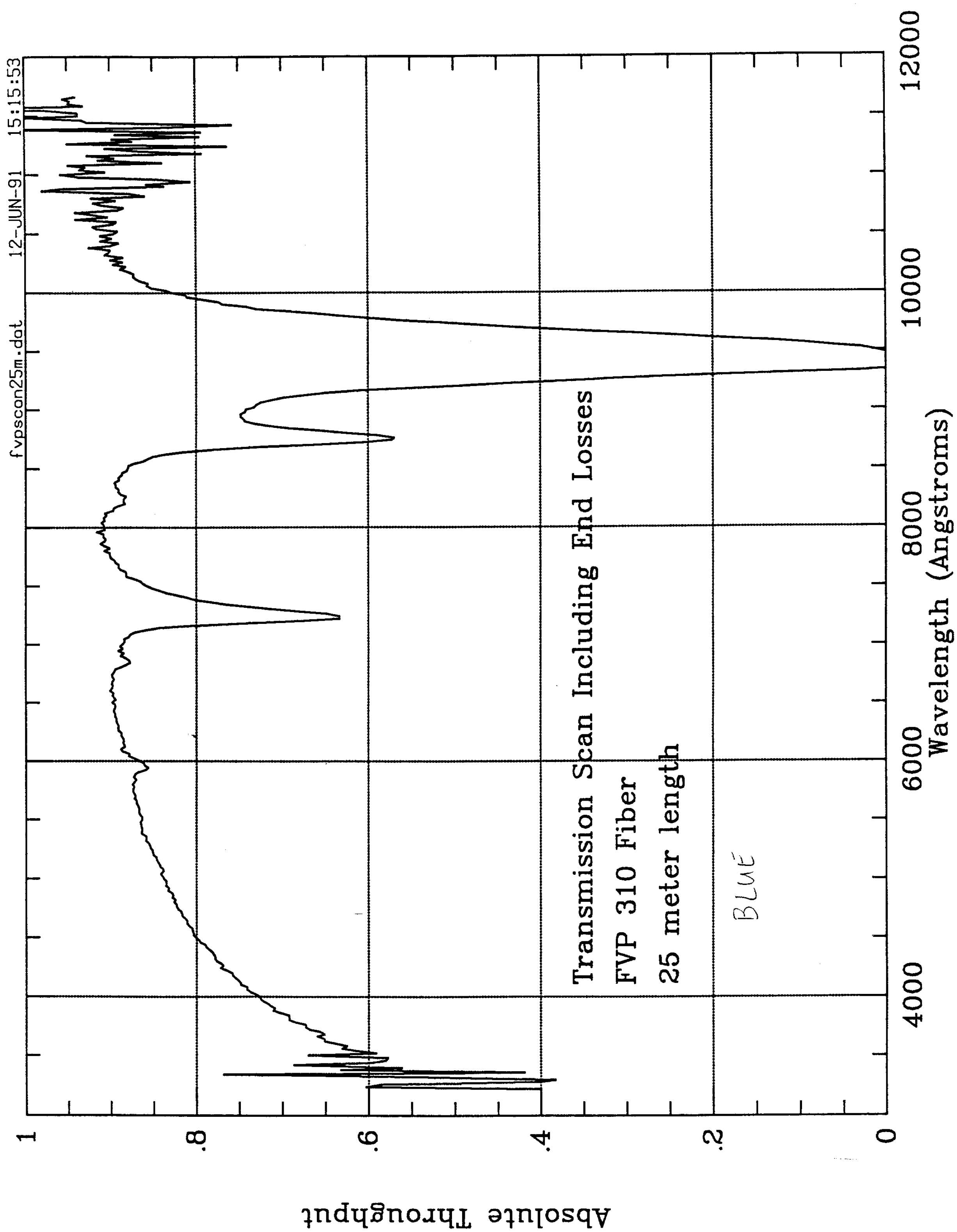
6. Conclusions

The optimum input f/ratio appears to be f/6. Complete radial scrambling is achieved and effectively all of the light can be collected by an f/5 collimator and 90% by an f/6 collimator.

I feel that this data set is representative of the typical fiber currently available and cabled in the manner to he used at the telescope. Previous evaluations of other fibers have shown the possibility of getting better FRD characteristics, however, extreme care was taken to handle those fibers in a way to minimize stress. A problem with the zero point level of the CCD video camera, while collecting the data for the earlier tests, may have led to slightly spurious and overly optimistic results.

7. Future Tests

I hope to evaluate the transmission of the same fiber with a prism mounted to the input end to determine additional losses due to the prism and epoxy. In addition, I would also like to evaluate the FRD and radial scrambling characteristics of a 5 meter fiber sample to get a handle on any length dependence (if the MOS were mounted on a Nasmyth focus, the fiber lengths may be reduced to 5-10 meters). These tests take time and it is uncertain whether I will complete them prior to the committee meeting in mid-July.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Transmission Scan Including End Losses
FVP 310 Fiber
25 meter length
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Absolute Throughput
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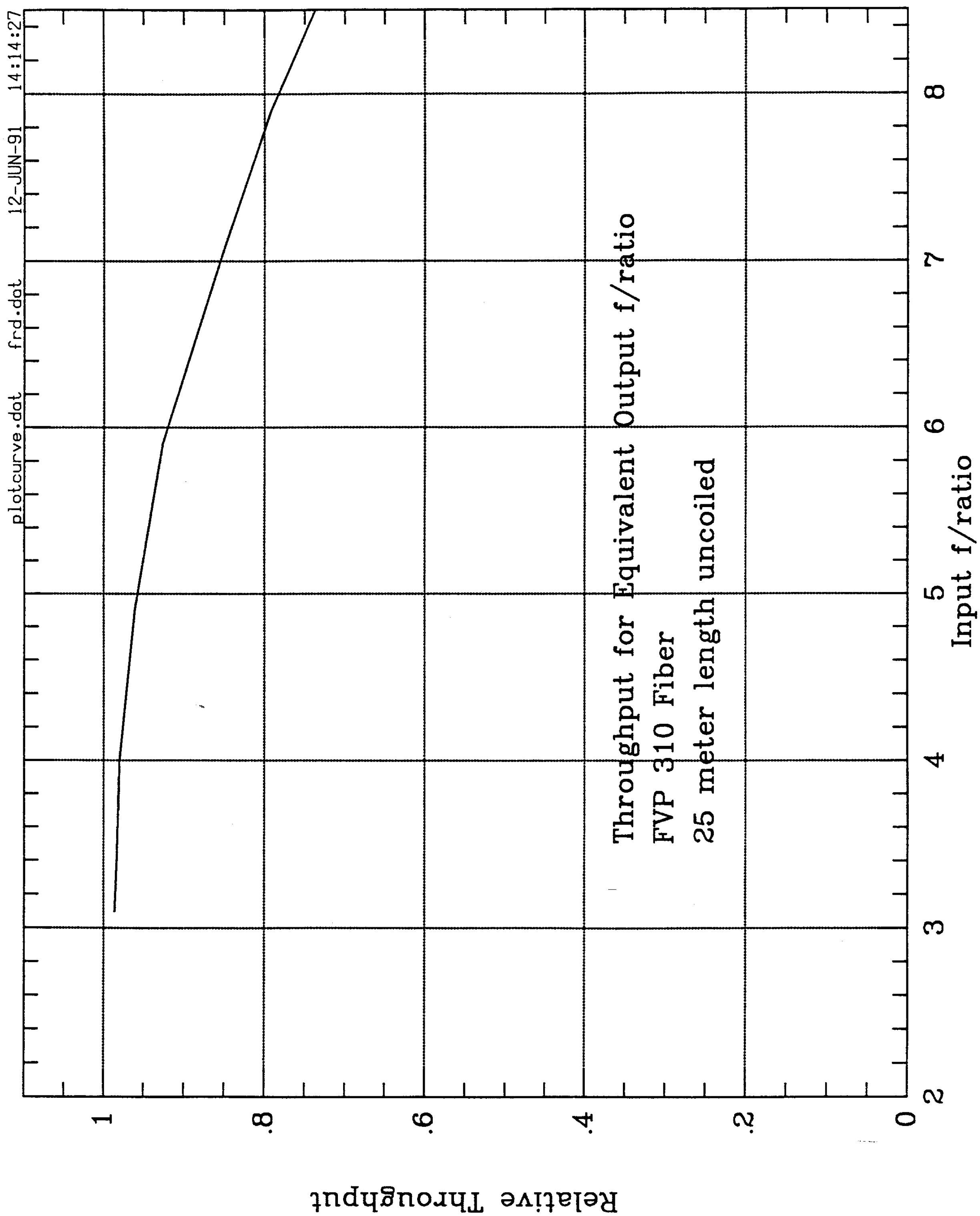
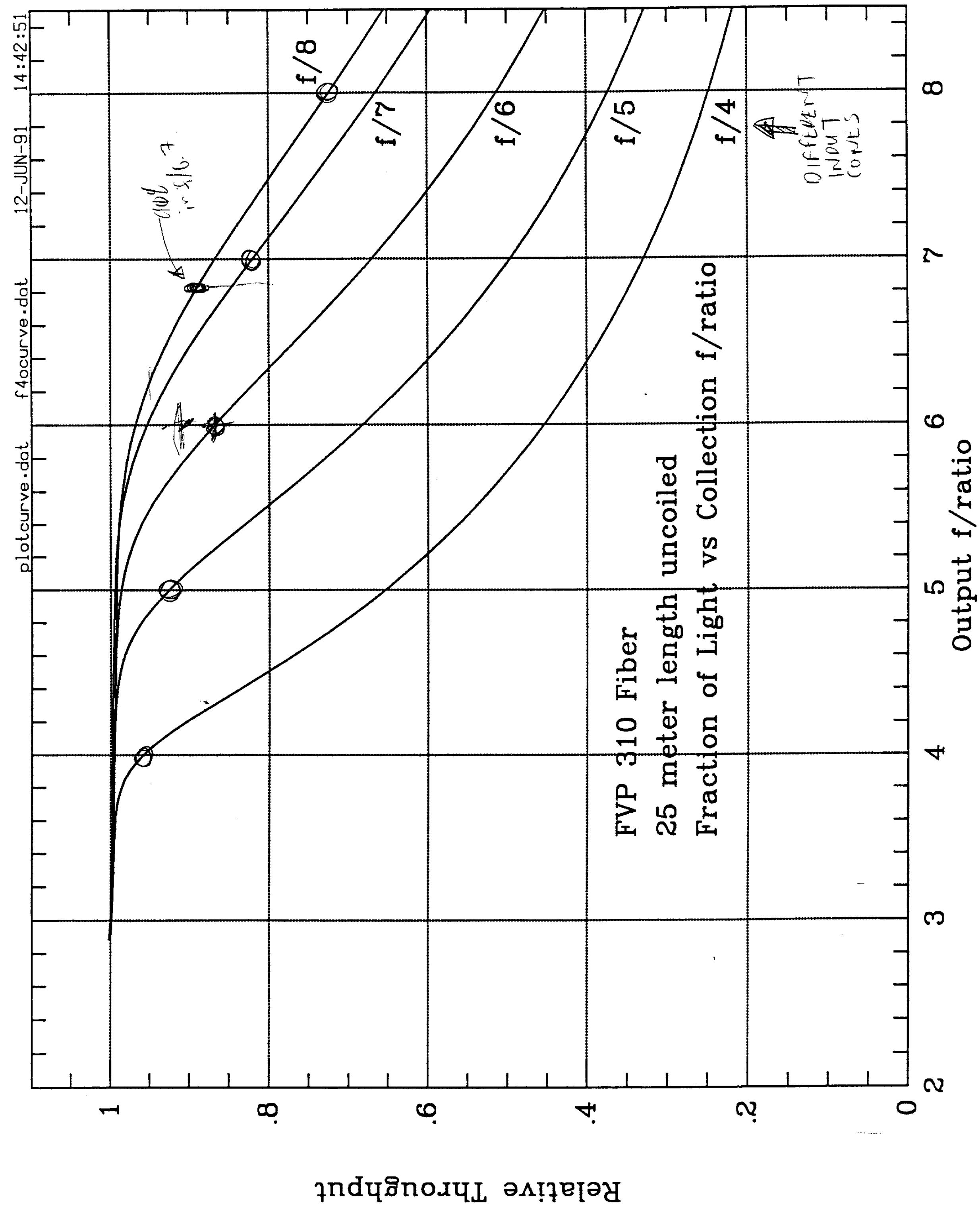
.2
.4
.6
.8
1
Wavelength (Angstroms)
4000
6000
8000
10000
12000


Throughput for Equivalent Output f/ratio
FVP 310 Fiber
25 meter length uncoiled
Input f/ratio
Relative Throughput
plotcurve.dat
frd.dat
12-JUN-91
14:14:27
2
3
4
5
6
7
8
0
.2
.4
.6
.8
1


FVP 310 Fiber
25 meter length uncoiled
Fraction of Light vs Collection f/ratio
Output f/ratio
Relative Throughput
f/8
f/7
f/6
f/5
f/4
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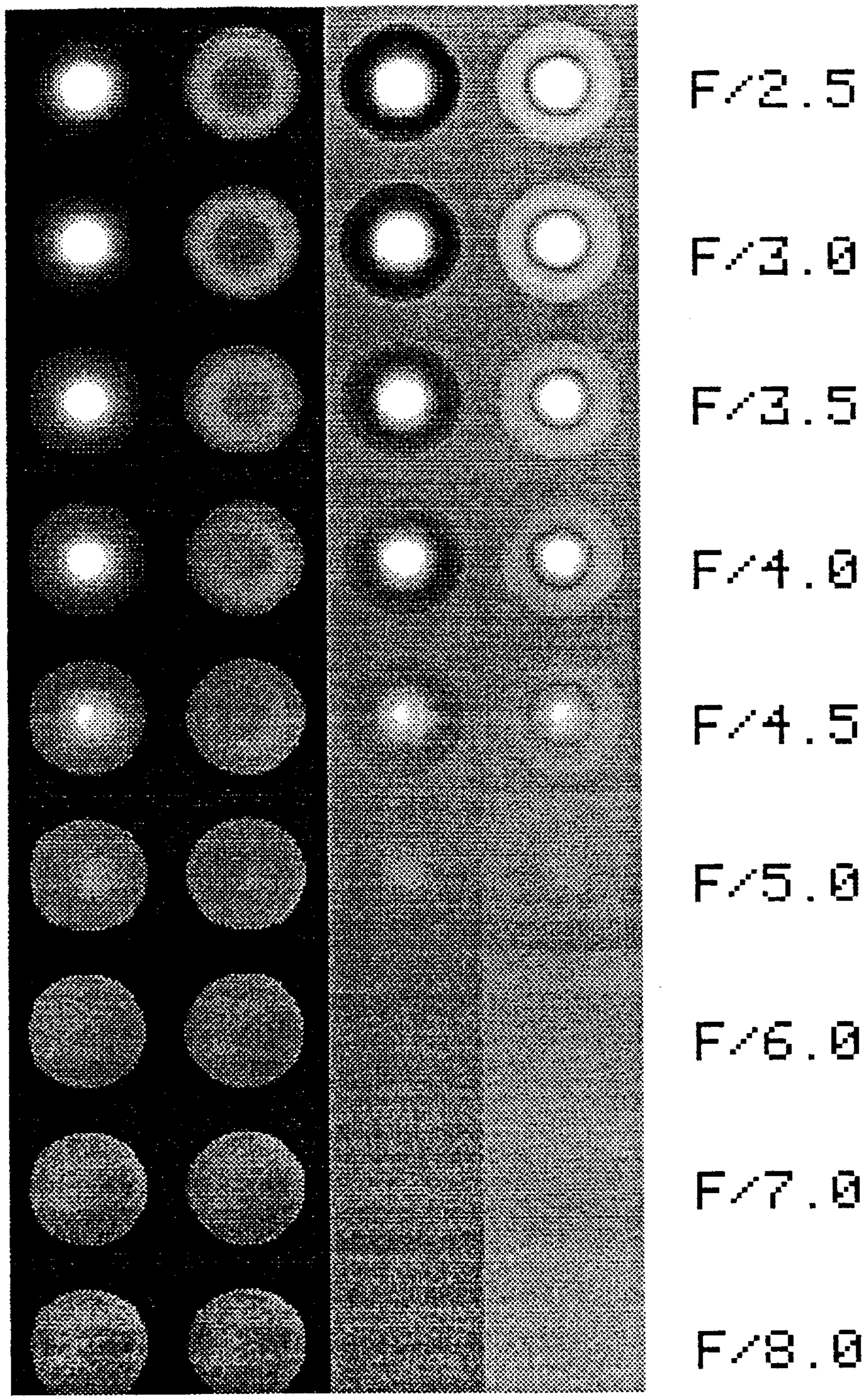
f4ocurve.dat
12-JUN-91
14:42:51
DIFFERENT
INPUT
CONES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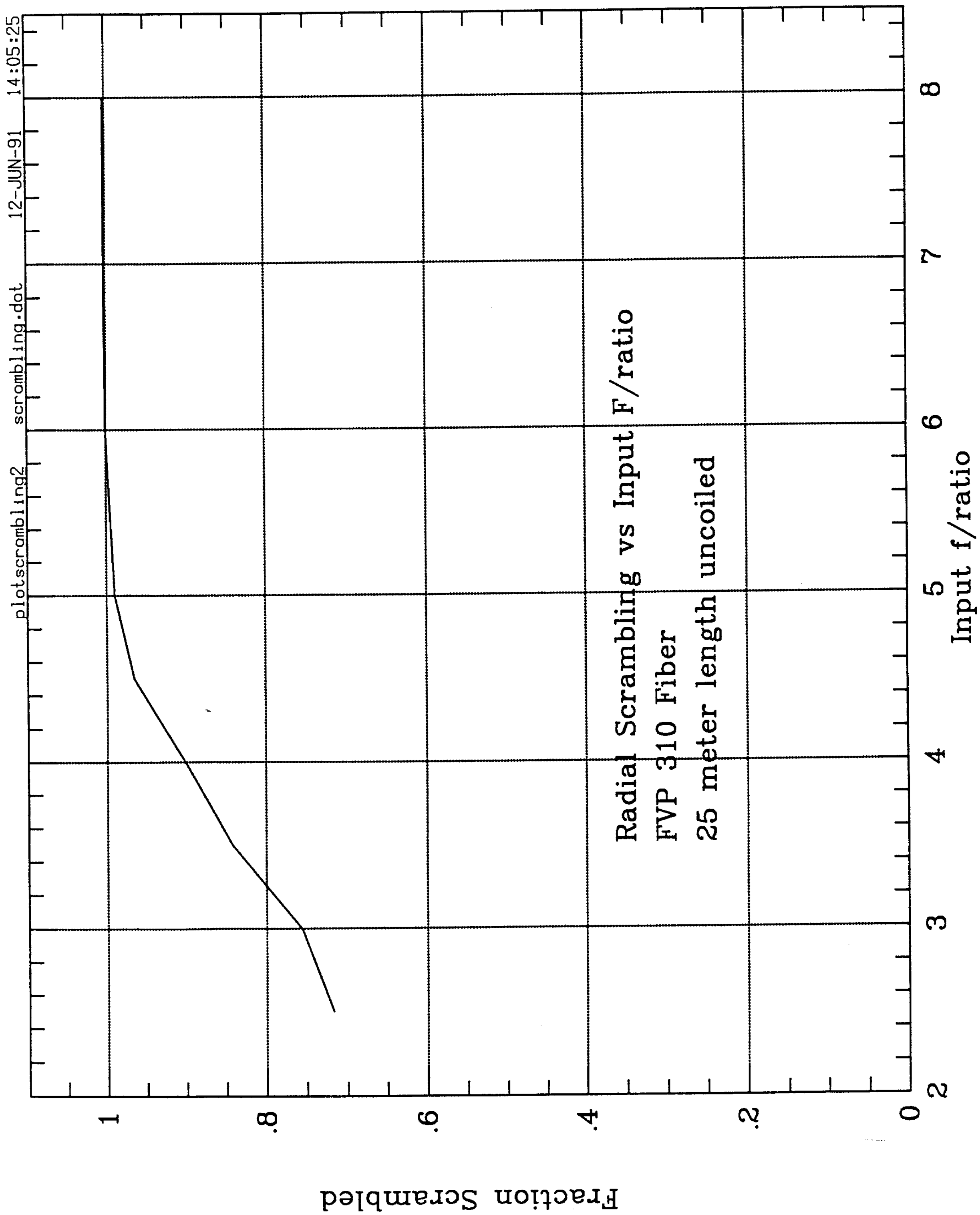
F/7.0
F/8.0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12-JUN-91
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Radial Scrambling vs Input F/ratio
FVP 310 Fiber
25 meter length uncoiled
Input f/ratio
Fraction Scrambled
0
.2
.4
.6
.8
1
2
3
4
5
6
7
8