

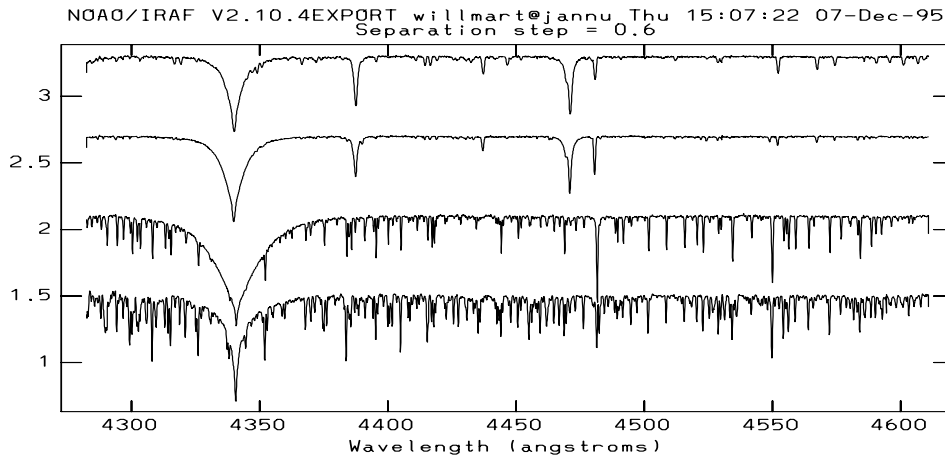
National
Optical
Astronomy
Observatories

Kitt Peak National Observatory

Instrumentation Operation Manual COUDÉ SPECTROGRAPH

Daryl Willmarth
Instrument Support Group
Kitt Peak National Observatory
National Optical Astronomy Observatories¹
P. O. Box 26732, Tucson, AZ 85726

January 5, 1996



¹Operated by the Association of Universities for Research in Astronomy, Inc. under cooperative agreement with the National Science Foundation

Contents

1	Introduction	1
2	Description of the Spectrograph	1
2.1	The Slit and Decker	2
2.2	Slit Viewing TV	3
2.3	Post-Slit Filter Holder	4
2.4	Collimators	4
2.5	Gratings	5
2.6	Cameras	5
2.6.1	Camera 5	6
2.6.2	Camera 6	6
2.7	Comparison Sources	6
3	CCD Use on the Coudé Spectrograph	10
3.1	Introduction	10
3.2	CCD Characteristics	12
3.3	Dewar Design and Maintenance	13
3.4	CCD Control System	15
3.5	CCD Camera Dewar on Spectrograph Camera 5	15
3.5.1	CCD Installation on Camera 5	15
3.5.2	Alignment of CCD Camera Dewar on Camera 5	17
3.6	CCD Dewar on Spectrograph Camera 6	19
3.6.1	Installation of CCD dewar on Camera 6	20
3.6.2	Alignment of the CCD Camera Head on Camera 6	21
4	Observing Philosophy	21
4.1	Observing Procedures	21
5	Data Reductions	23
6	Computer Operation	24
6.1	Logging In, Initializing ICE, and Logging Out	24
6.2	Parameter Sets	24
6.3	Data Acquisition Tasks	25
6.4	Image Tasks	25
6.5	Tape Tasks	26
6.6	Miscellaneous Tasks	26
7	The Coudé Feed Telescope	26
7.1	Open-up Procedure	26
7.2	Setting the Grating	27
7.3	Finding Stars	27

7.4	Guiding With the DTI-21 Leaky Guider	28
7.5	Typical Observing Procedure	28
7.6	Feed Telescope Shutdown Procedure	28
7.7	Coudé Image Rotator	29

List of Tables

1	Slit Parameters	2
2	Decker No. 1 – with comparison slots	2
3	Decker No. 2 – no comparison slots	3
4	Coude spectrograph collimators	5
5	Coude spectrograph gratings	6
6	RC grating use on coude spectrograph	7
7	Cross dispersing grisms	7
8	31.6 g/mm, 63° echelle grating parameters for camera 5	8
9	31.6 g/mm, 63° echelle grating paramters for camera 6	9
10	Coudé spectrograph cameras	11
11	Spectrum widths for camera 5 – decker plate 1	12
12	Spectrum widths for camera 5 – decker plate 2	13
13	Spectrum widths for camera 6 – decker plate 1	14
14	Spectrum widths for camera 6 – decker plate 2	15
15	Coude camera performance using CCDs	16
16	CCD characteristics	17
17	Projected image slice dimensions on camera 6	20

List of Figures

1	Coudé spectrograph optical diagram.	1
2	Commonly used coudé filters.	4
3	Order Separations for 31.6 g/mm Echelle.	10
4	CCD Quantum Efficiencies.	18
5	Theoretical S/N Values per Pixel for CCDs.	22
6	Sky Coverage for Coude Feed.	30

1 Introduction

The specification and operation of the Kitt Peak coude spectrograph are described in this manual, intended for use by visiting astronomers and Kitt Peak support staff. Instructions and software for CCD setup and use as well as the auxillary feed telescope are included. Observers are cautioned not to attempt any of the adjustments described herein without prior approval of KPNO staff.

The coude spectrograph is a versatile instrument capable of intermediate to high resolution ($\sim 3.6 \text{ \AA} - 20 \text{ m\AA}$) over a wide range of wavelengths ($3000 \text{ \AA} - 16,000 \text{ \AA}$). This manual discusses only the use of CCD systems on the coude spectrograph. While in principle photographic plates could still be used, it has been several years since their last use. Near infra-red wavelengths can presently be accessed with the NICMASS camera, a 256×256 HgCdTe array installed at the camera 5 focus. The March, 1995 NOAO Newsletter (Number 41) contains more details on the use of this camera.

The spectrograph is presently used only with the 0.9 m coude feed telescope.

An instrument assistant is normally present on the first day and evening of an observer's run to help set up and focus the spectrograph. Guiding of the star on the slit may be done automatically with the ICCD viewing TV and digital memory.

2 Description of the Spectrograph

In this section a description of each element of the spectrograph is given, progressing through the light path. The optical diagram shown in fig. 1 may be consulted for the arrangement of these elements.

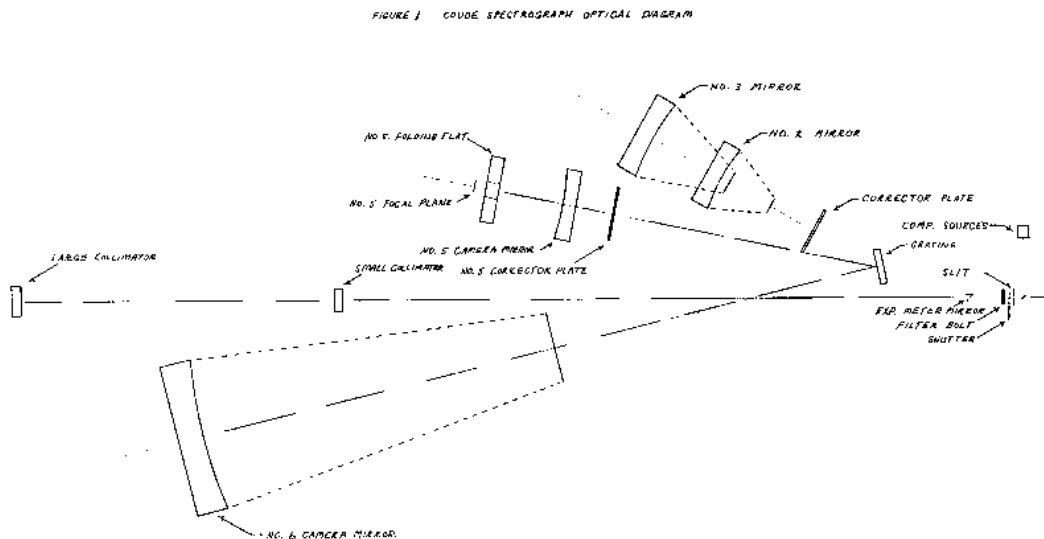


Figure 1: Coude spectrograph optical diagram.

2.1 The Slit and Decker

The slit specifications are given below and the stellar and comparison decker dimensions are listed in tables 2 and 3. There are two decker plates available; decker plate No. 1 is a conventional decker plate with comparison slots for photographic use. Decker No. 2 has no comparison slots and is used mainly with CCDs. It has two sets of openings to accommodate different seeing and demagnifications. When setting the slit width, close it all the way and then open it up to the desired width. Although the slit width will indicate down to 0.0 mm, the minimum opening is 27 microns.

Slit Parameters

Scale using 2.1 m telescope	3.10 arc-sec mm ⁻¹
Scale using feed telescope	7.23 arc-sec mm ⁻¹
Maximum slit length	25.68 mm
Maximum slit width	1.25 mm
Minimum slit width	0.027 mm
Slit width scale	1 vernier div. = 0.001 mm

Table 1: Slit Parameters

Decker No. 1 – with comparison slots					
decker	stellar length			comparison length	
	length (mm)	2.1 m (arc-sec)	Feed (arc-sec)	inner (mm)	outer (mm)
1	25.68	79.6	185.7	28.27	47.67
2	18.12	56.2	131.0	20.06	39.99
3	9.04	28.0	65.4	11.02	30.90
4	6.42	19.9	46.4	8.42	20.32
5	4.46	13.8	32.2	6.44	18.40
6	3.14	9.7	22.7	3.84	7.03
7	2.23	6.9	16.1	2.91	6.05
8	1.59	4.9	11.5	2.14	5.42
9	1.08	3.3	7.8	1.72	4.92
10	0.62	1.9	4.5	1.27	4.42

Table 2: Decker No. 1 – with comparison slots

Decker No. 2 – no comparison slots			
decker	stellar length		
	length (mm)	2.1 m (arc-sec)	feed (arc-sec)
small set			
1	0.68	2.1	4.9
2	0.56	1.7	4.0
3	0.44	1.4	3.2
4	0.36	1.1	2.6
5	0.29	0.9	2.1
6	0.24	0.7	1.7
7	0.20	0.6	1.4
8	0.17	0.5	1.2
9	0.13	0.4	0.9
10	0.09	0.3	0.6
large set			
1	9.77	30.3	70.6
2	4.98	15.4	36.0
3	3.99	12.4	28.8
4	3.20	9.9	23.1
5	2.56	7.9	18.5
6	2.07	6.4	15.0
7	1.68	5.2	12.1
8	1.34	4.2	9.7
9	1.08	3.3	7.8
10	0.89	2.8	6.4

Table 3: Decker No. 2 – no comparison slots

2.2 Slit Viewing TV

The slit and decker assembly is mounted at an angle of 13° to reflect light from the slit jaws to an intensified CCD TV for acquisition and guiding. A zoom lens is installed before the TV for changing the field of view and optimizing the apparent slit width in the digital memory guider box. A slit width of about one third the width of the guider box will be satisfactory for auto-guiding. See §7.4 for a discussion of operating the leaky memory guider. The AC power switch on the left side of the slit head control panel must be on to operate the zoom lens, but it may be controlled either at the panel or by buttons on the coude observing room control rack.

2.3 Post-Slit Filter Holder

This 2" x 2" (50.8 mm x 50.8 mm) filter holder has 2 filter positions, plus open, as determined by detents on the filter slide. When the filter bolt lever is pushed all the way in, the left filter is in the beam. Pulling the filter bolt lever out to the first detent places the right filter in the beam. When the filterbolt lever is pulled all the way out to the stop, no filters are in the beam. Transmission curves for some of the more commonly used order separation filters are shown in figure 2. Measured transmission curve plots for each filter available at the coude spectrograph are shown in a manual kept at the telescope. Other special filters are available on advance notice, or observers may bring their own.

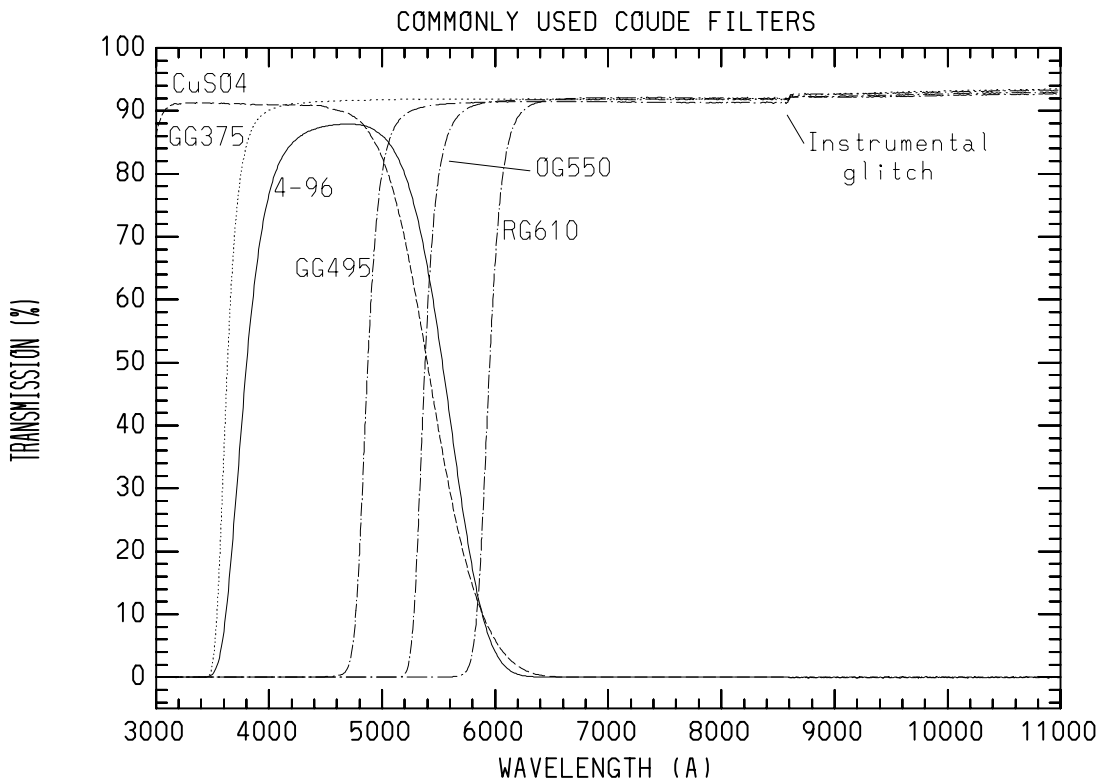


Figure 2: Commonly used coude filters.

2.4 Collimators

Two collimators are available; the large one is used with gratings A and B, and the small collimator is used with gratings C, D, echelle, and any of the RC gratings. The large collimator has the advantage of higher demagnification, allowing a wider slit width for the same resolution on the detector. The specifications of both collimators are given in table 4.

Coudé Spectrograph Collimators				
	f/ratio	focal length (m)	pt. source dia. (mm)	gratings
small col	31.2	6.86	221.0	C, D, echelle, RC
large col	31.2	10.11	325.1	A, B

Table 4: Coude spectrograph collimators

2.5 Gratings

Six gratings are presently available at the coudé spectrograph and their specifications are given in table 5. Gratings used with the 4 m RC spectrograph may also be requested in advance for use with CCDs to yield lower resolutions. Table 6 lists the specifications of the RC gratings.

The grating tilt for a particular camera and wavelength may be set by using the grating control window on the telescope control computer terminal (§7.2). Note that the grating drive stepper-motor power supply switches, located on the slit-head control panel (AC power), and the observing room rack panel, must both be turned on in order for the grating drive to function. The setting accuracy of the stepper-motor varies from about 1 to 5 Å depending upon the grating and order, although there may be an offset due to camera realignment or different CCD. The power switch in the observing room should be turned off after setting to insure against possible motion.

If using third order with grating A or B, interference from 4th order may be a problem at some wavelengths. Use of the echelle grating requires a grism cross disperser (Table 7) or narrow band filter to isolate the order of interest. Tables 8 and 9 are lists of echelle orders, central wavelengths, and dispersions for the echelle grating on cameras 5 and 6. Figure 3 shows the relation between order separation and grism distance below the slit for the various grisms and the 31.6 g/mm echelle. The spectral coverage between the highest and lowest orders varies from roughly 1500Å for the grisms used in first order, to 700Å in second order. Plots for each grism are kept in a notebook at the spectrograph.

NOTE: ALL grating changes should be done only by technical assistants or instrument assistants. Care must be used in locating grisms to avoid the region from 48 to 70 inches below the slit. In this region, collisions between the grating cell holder and the grism can occur.

2.6 Cameras

Table 10 contains a summary of the characteristics of cameras 5 and 6. The resolutions, spectral coverages, and typical exposure times for different camera-grating combinations are summarized in table 15. This information may be used to help determine the proper camera for a particular observing project.

Coudé Spectrograph Gratings					
designation	A	B	C*	D*	echelle
ruled area (mm)	304 x 361	309 x 370	204 x 254	204 x 308	203 x 381
grooves-mm ⁻¹	632	316	600	1200	31.6
blaze (Å), first order	12000	12000	8000	8000	562,560**
ghost intensity (%)	0.005	0.002	0.06	0.1	
*double diamond ruling					
**for camera 5					

Table 5: Coude spectrograph gratings

2.6.1 Camera 5

Camera 5 is a folded Schmidt design with the CCD dewar mounted behind the spherical mirror. Tables 11 and 12 list the projected decker sizes for stellar and comparison deckers.

2.6.2 Camera 6

Camera 6, the longest focal length camera, lies on the east side of the collimator beam and therefore requires the grating to be rotated 180 degrees about its normal. Specifications for camera 6 can be found in table 10 and projected decker sizes are listed in tables 13 and 14. Typical focus steps are 0.20 mm.

2.7 Comparison Sources

The comparison sources are mounted on a post to the right of the slit head, and are selected by a rotatable mirror. The following sources are currently available:

1. Th-Ar hollow cathode or Fe-Ar hollow cathode.
2. Ne-Ar.
3. Quartz-Iodide.

The Fe-Ar hollow cathode is less rich than the Th-Ar lamp and may be useful with the lower dispersion RC gratings. The Ne-Ar lamp has few bright lines shortward of 5800 Å so is used exclusively for red work. For high dispersion work the Th-Ar lamp may be required to obtain a sufficient number of lines in the spectral region of interest. Wavelength plots of these lamps may be found in the appropriate *CCD Atlas of Comparison Spectra...* which are kept at the coude spectrograph. Copies can also be obtained in the downtown Kitt Peak Support office.

The QI lamp is used with the CCD detector to provide flat field illumination for calibration of small scale detector response.

RC Grating Use On Coude Spectrograph								
RC grating	grooves per mm	blaze $\lambda(\text{\AA})$ first ord.	disp.($\text{\AA}/\text{mm}$) first ord.		res.(\AA) first ord.*		spect. cov.(\AA) first ord.**	
			cam. 5	Cam. 6	Cam. 5	Cam. 6	Cam. 5	Cam. 6
250	158	4000	60	17	1.8	0.51	739	209
400	158	8000	60	17	1.8	0.51	739	209
KPC-10A	316	4000	30	8.4	0.9	0.25	370	103
181	316	7500	30	8.4	0.9	0.25	370	103
KPC-007	632	5200	15	4.2	0.45	0.13	185	52
450	632	11,000	15	4.2	0.45	0.13	185	52
KPC-17B	527	5540	18	5.3	0.54	0.16	232	66
KPC-18C	790	8500	12	3.3	0.36	0.10	146	41

*for two 15μ pixels; scale for other CCD
**for F3KB CCD, 3072 pixels; scale for other CCD

Table 6: RC grating use on coude spectrograph

A set of neutral density filters is available at the coude spectrograph for controlling lamp brightness. These mount on filter holders just in front of the source exit window and can be rotated in and out of the beam. For CCD observing, use the diffusers instead of n.d. filters to avoid periodic fringing in the data.

The other optical element required for the comparison sources consists of a small mirror which can be manually moved over the slit to send the light into the spectrograph. This mirror has two modes of operation:

1. For photographic work where one wants the comparison spectra on each side of the stellar spectra, turn the comparison decker knob counter-clockwise until it stops. Then slide the comparison mirror to the right using **only** the aluminum handle on the left of

Cross Dispersing Grisms						
grism no.	650	770	810	730	780	780-2
grooves/mm	400	300	150	300	300	300
wedge angle ($^\circ$)	19.00	17.22	10.80	22.35	23.75	25.2
UDCW* (\AA , 1st order)	4950	5970	6360	8010	9700	7300
UDCW* (\AA , 2nd order)				4300	4850	3800
glass type	BAF4	F2	BK7	SF2	SF4	UBK7

*Undeviated Central Wavelength

Table 7: Cross dispersing grisms

Order	Blaze(Å)	FSR	Recip. Disp.	Order	Blaze(Å)	FSR	Recip. Disp.
55.	10228.	186.	2.92	116.	4850.	42.	1.38
56.	10046.	179.	2.86	117.	4808.	41.	1.37
57.	9869.	173.	2.81	118.	4767.	40.	1.36
58.	9699.	167.	2.77	119.	4727.	40.	1.35
59.	9535.	162.	2.72	120.	4688.	39.	1.34
60.	9376.	156.	2.67	121.	4649.	38.	1.33
61.	9222.	151.	2.63	122.	4611.	38.	1.31
62.	9074.	146.	2.59	123.	4574.	37.	1.30
63.	8929.	142.	2.55	124.	4537.	37.	1.29
64.	8790.	137.	2.51	125.	4500.	36.	1.28
65.	8655.	133.	2.47	126.	4465.	35.	1.27
66.	8524.	129.	2.43	127.	4430.	35.	1.26
67.	8396.	125.	2.39	128.	4395.	34.	1.25
68.	8273.	122.	2.36	129.	4361.	34.	1.24
69.	8153.	118.	2.32	130.	4327.	33.	1.23
70.	8037.	115.	2.29	131.	4294.	33.	1.22
71.	7923.	112.	2.26	132.	4262.	32.	1.22
72.	7813.	109.	2.23	133.	4230.	32.	1.21
73.	7706.	106.	2.20	134.	4198.	31.	1.20
74.	7602.	103.	2.17	135.	4167.	31.	1.19
75.	7501.	100.	2.14	136.	4136.	30.	1.18
76.	7402.	97.	2.11	137.	4106.	30.	1.17
77.	7306.	95.	2.08	138.	4077.	30.	1.16
78.	7212.	92.	2.06	139.	4047.	29.	1.15
79.	7121.	90.	2.03	140.	4018.	29.	1.15
80.	7032.	88.	2.01	141.	3990.	28.	1.14
81.	6945.	86.	1.98	142.	3962.	28.	1.13
82.	6860.	84.	1.96	143.	3934.	28.	1.12
83.	6778.	82.	1.93	144.	3907.	27.	1.11
84.	6697.	80.	1.91	145.	3880.	27.	1.11
85.	6618.	78.	1.89	146.	3853.	26.	1.10
86.	6541.	76.	1.87	147.	3827.	26.	1.09
87.	6466.	74.	1.84	148.	3801.	26.	1.08
88.	6393.	73.	1.82	149.	3776.	25.	1.08
89.	6321.	71.	1.80	150.	3750.	25.	1.07
90.	6251.	69.	1.78	151.	3726.	25.	1.06
91.	6182.	68.	1.76	152.	3701.	24.	1.06
92.	6115.	66.	1.74	153.	3677.	24.	1.05
93.	6049.	65.	1.72	154.	3653.	24.	1.04
94.	5985.	64.	1.71	155.	3629.	23.	1.03
95.	5922.	62.	1.69	156.	3606.	23.	1.03
96.	5860.	61.	1.67	157.	3583.	23.	1.02
97.	5800.	60.	1.65	158.	3560.	23.	1.02
98.	5740.	59.	1.64	159.	3538.	22.	1.01
99.	5682.	57.	1.62	160.	3516.	22.	1.00
100.	5626.	56.	1.60	161.	3494.	22.	1.00
101.	5570.	55.	1.59	162.	3473.	21.	0.99
102.	5515.	54.	1.57	163.	3451.	21.	0.98
103.	5462.	53.	1.56	164.	3430.	21.	0.98
104.	5409.	52.	1.54	165.	3409.	21.	0.97
105.	5358.	51.	1.53	166.	3389.	20.	0.97
106.	5307.	50.	1.51	167.	3369.	20.	0.96
107.	5258.	49.	1.50	168.	3349.	20.	0.95
108.	5209.	48.	1.49	169.	3329.	20.	0.95
109.	5161.	47.	1.47	170.	3309.	19.	0.94
110.	5114.	46.	1.46	171.	3290.	19.	0.94
111.	5068.	46.	1.45	172.	3271.	19.	0.93
112.	5023.	45.	1.43	173.	3252.	19.	0.93
113.	4978.	44.	1.42	174.	3233.	19.	0.92
114.	4935.	43.	1.41	175.	3215.	18.	0.92
115.	4892.	43.	1.39	176.	3196.	18.	0.91

Table 8: 31.6 g/mm, 63° echelle grating parameters for camera 5

Order	Blaze(\AA)	FSR	Recip. Disp.	Order	Blaze(\AA)	FSR	Recip. Disp.
55.	10247.	186.	0.83	116.	4863.	42.	0.39
56.	10064.	179.	0.81	117.	4821.	41.	0.39
57.	9888.	173.	0.80	118.	4781.	40.	0.39
58.	9717.	167.	0.79	119.	4740.	40.	0.38
59.	9553.	162.	0.77	120.	4701.	39.	0.38
60.	9393.	156.	0.76	121.	4662.	38.	0.38
61.	9239.	151.	0.75	122.	4624.	38.	0.37
62.	9090.	146.	0.74	123.	4586.	37.	0.37
63.	8946.	142.	0.72	124.	4548.	37.	0.37
64.	8806.	137.	0.71	125.	4513.	36.	0.36
65.	8671.	133.	0.70	126.	4477.	35.	0.36
66.	8540.	129.	0.69	127.	4442.	35.	0.36
67.	8412.	125.	0.68	128.	4407.	34.	0.36
68.	8288.	122.	0.67	129.	4373.	34.	0.35
69.	8168.	118.	0.66	130.	4339.	33.	0.35
70.	8052.	115.	0.65	131.	4306.	33.	0.35
71.	7938.	112.	0.64	132.	4273.	32.	0.34
72.	7828.	109.	0.63	133.	4241.	32.	0.34
73.	7721.	106.	0.62	134.	4210.	31.	0.34
74.	7616.	103.	0.62	135.	4179.	31.	0.34
75.	7515.	100.	0.61	136.	4148.	30.	0.33
76.	7416.	97.	0.60	137.	4118.	30.	0.33
77.	7320.	95.	0.59	138.	4088.	30.	0.33
78.	7226.	92.	0.58	139.	4058.	29.	0.33
79.	7134.	90.	0.58	140.	4029.	29.	0.32
80.	7045.	88.	0.57	141.	4001.	28.	0.32
81.	6958.	86.	0.56	142.	3973.	28.	0.32
82.	6873.	84.	0.56	143.	3945.	28.	0.32
83.	6790.	82.	0.55	144.	3917.	27.	0.32
84.	6710.	80.	0.54	145.	3890.	27.	0.31
85.	6631.	78.	0.54	146.	3864.	26.	0.31
86.	6554.	76.	0.53	147.	3837.	26.	0.31
87.	6478.	74.	0.52	148.	3811.	26.	0.31
88.	6405.	73.	0.52	149.	3786.	25.	0.31
89.	6333.	71.	0.51	150.	3761.	25.	0.30
90.	6262.	69.	0.51	151.	3733.	25.	0.30
91.	6194.	68.	0.50	152.	3708.	24.	0.30
92.	6126.	66.	0.50	153.	3684.	24.	0.30
93.	6060.	65.	0.49	154.	3660.	24.	0.30
94.	5996.	64.	0.49	155.	3636.	23.	0.29
95.	5933.	62.	0.48	156.	3613.	23.	0.29
96.	5871.	61.	0.48	157.	3590.	23.	0.29
97.	5810.	60.	0.47	158.	3567.	23.	0.29
98.	5751.	59.	0.47	159.	3545.	22.	0.29
99.	5693.	57.	0.46	160.	3523.	22.	0.28
100.	5636.	56.	0.46	161.	3501.	22.	0.28
101.	5585.	55.	0.45	162.	3479.	21.	0.28
102.	5530.	54.	0.45	163.	3458.	21.	0.28
103.	5477.	53.	0.44	164.	3437.	21.	0.28
104.	5424.	52.	0.44	165.	3416.	21.	0.28
105.	5372.	51.	0.43	166.	3395.	20.	0.27
106.	5322.	50.	0.43	167.	3375.	20.	0.27
107.	5272.	49.	0.43	168.	3355.	20.	0.27
108.	5223.	48.	0.42	169.	3335.	20.	0.27
109.	5175.	47.	0.42	170.	3315.	19.	0.27
110.	5128.	46.	0.41	171.	3296.	19.	0.27
111.	5082.	46.	0.41	172.	3277.	19.	0.26
112.	5037.	45.	0.41	173.	3258.	19.	0.26
113.	4992.	44.	0.40	174.	3239.	19.	0.26
114.	4948.	43.	0.40	175.	3221.	18.	0.26
115.	4905.	43.	0.40	176.	3202.	18.	0.26

Table 9: 31.6 g/mm, 63° echelle grating paramters for camera 6

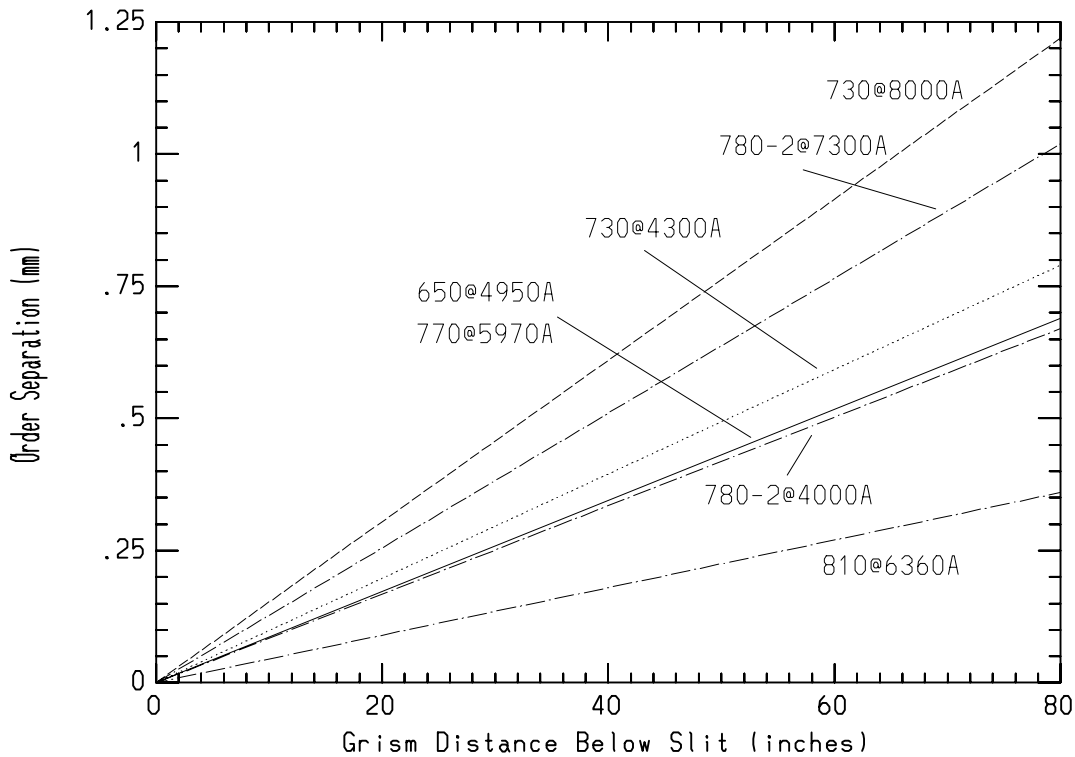


Figure 3: Order Separations for 31.6 g/mm Echelle.

this device. For CCD use, the second mode is generally used.

2. For CCD work where one wants to expose the comparison lamp only through the stellar decker, simply slide the mirror to the right manually using **only** the aluminum handle on the left of this device.

3 CCD Use on the Coudé Spectrograph

3.1 Introduction

The introduction of CCD (Charge Coupled Device) detectors at the coude spectrograph in 1982 initiated the employment of these low noise linear devices in medium to high resolution spectroscopy. This technology enables observers to obtain data of higher signal to noise and larger dynamic range than previously obtainable with conventional photographic or image tube techniques. The resulting data has the added convenience of being in digital form, ready for subsequent analysis.

Coudé Spectrograph Cameras		
Parameter	Camera Number	
	5	6
f-ratio	3.6	16
f-length(cm)	108.0	365.3
demagnification		
-small collimator	6.3	1.9
-large collimator	9.4	3.0

Table 10: Coudé spectrograph cameras

The CCD Universal dewars can be mounted either on camera 5 or 6. Table 16 may be consulted for the operating characteristics of the CCDs on these cameras. Section 2.6 should be consulted for additional information concerning these cameras. There are also a number of gratings used in the 4 m RC spectrograph which are usable on the coudé spectrograph with a special adapter. These gratings are approximately the size of gratings “C” and “D” and use the small collimator. Table 5 lists useful parameters for these gratings. It is important to note that their use depends upon their scheduling at the 4 m and requires advance notice. An 8” x 15”, 31.6 g/mm, 63° echelle grating became available for use in the fall of 1988. On camera 5, this grating yields a demagnification of ~ 12 and a resolution of $\sim 100,000$; in other words a very large slit can be used and still obtain high resolution. On camera 6 the demagnification is ~ 3 and the resolution is $\sim 200,000$. Cross-dispersion of the echelle is accomplished by the use of a grism located ~ 1 meter below the slit and allows the recording of 15 – 20 orders per integration. As with the RC gratings, the grisms are “borrowed” and their use depends upon the scheduling of the Cryogenic camera.

Observers wishing to measure precision radial velocities may want to use a fiber optic image scrambler. This device consists of 1 fiber for the star and two fibers to monitor a comparison lamp. The stellar fiber reduces the effect of guiding errors and refraction, while the comparison fibers monitor the small motions of the CCD during the night. An IRAF program (DOFIBERS) is available for reduction of this type of data. The main disadvantage of the fiber is its throughput; about 60% of that of a slit.

An image slicer is available which may be useful for certain types of observing on camera 6. The slicer is of the Bowen-Walraven type which produces 10 slices stacked end-to-end, each 40μ wide and 0.5 mm tall. The slicer is constructed of quartz for good uv transmission. The entrance aperture is about 500μ square (3.6 arc-sec with coude feed). §3.6 contains more details on the use of the image slicer.

With the aid of the IRAF routines on the Sun computer, observers can leave the mountain with data that has been reduced; that is free of instrumental effects. These reductions include subtraction of bias counts, division by flat spectra to eliminate small scale detector response, and compression to a one dimensional spectrum. Wavelength calibration, continuum

Spectrum Widths for Camera 5 – Decker Plate 1						
	Stellar (mm)		Comparison (mm)			
Decker	Small Col.	Large Col.	Small Col.		Large Col.	
			Inner	Outer	Inner	Outer
1	4.08	2.73	4.49	7.57	3.01	5.07
2	2.88	1.93	3.18	6.35	2.13	4.25
3	1.43	0.96	1.75	4.90	1.17	3.29
4	1.02	0.68	1.34	3.22	0.90	2.16
5	0.71	0.47	1.02	2.92	0.68	1.96
6	0.50	0.33	0.61	1.12	0.41	0.75
7	0.35	0.24	0.46	0.96	0.31	0.64
8	0.25	0.17	0.34	0.86	0.23	0.58
9	0.17	0.11	0.27	0.78	0.18	0.52
10	0.10	0.07	0.20	0.70	0.14	0.47

Table 11: Spectrum widths for camera 5 – decker plate 1

rectification and analysis can also be done as need and time allow.

3.2 CCD Characteristics

Presently, the dedicated CCD at the coudé spectrograph is a Ford 3K x 1K CCD. There is also a TI thinned 800 x 800 CCD available on advance request. This latter chip has slightly better resolution than the Ford CCD, but significantly smaller spectral coverage (25%). The operating characteristics of these devices are given in Table 16 and a graph of the quantum efficiency vs. wavelength is shown in Figure 4. The *CCD Characteristics Manual* (a copy is kept at each telescope) has pictures of each CCD which show the bad columns and other cosmetic details.

TI CCDs suffer from a small degree of charge transfer inefficiency at low light levels ($< \sim 25$ ADUs¹). This can be a problem when looking at weak emission lines without background continuum. A low level of “preflash” is sometimes used to bring the background up to about 20 ADUs to alleviate this problem. It is not generally a problem on normal stellar spectra where the continuum level brings the signal up to a sufficiently high level. Please discuss this technique with your instrument assistant. Aligning the spectrum parallel to rows on TI CCDs will also alleviate the charge transfer problem along the dispersion.

The CCD can currently be operated in two different observing modes: with on-chip pixel summing, or without. In the on-chip summing mode pixel size can be any integral number of pixels in one or both dimensions. The readout noise per pixel is still approximately the same as that of one pixel even though the charges from several pixels per resolution element

¹Analog to Digital Units

Spectrum Widths for Camera 5 – Decker Plate 2				
	Small Set (mm)		Large Set (mm)	
Decker	Small Col.	Large Col.	Small Col.	Large Col.
1	0.108	0.072	1.551	1.039
2	0.089	0.060	0.790	0.530
3	0.070	0.047	0.633	0.424
4	0.057	0.038	0.508	0.340
5	0.046	0.031	0.406	0.272
6	0.038	0.026	0.329	0.220
7	0.032	0.021	0.267	0.179
8	0.027	0.018	0.213	0.143
9	0.021	0.014	0.171	0.115
10	0.014	0.010	0.141	0.095

Table 12: Spectrum widths for camera 5 – decker plate 2

are summed together. The amount of pixel summing is set in the DETPARS task (§6.2). While the readout noise per resolution element can be reduced in this manner, one must consider how the data will be reduced to arrive at the optimal pixel size. For example, the DOSLIT task works with the spatial profile of the spectrum to find cosmic rays and will not be effective if the spectrum is too narrow. It is important to realize that the CCD response will become non-linear above certain ADU levels. For the TI CCD's this is $\sim 7,000$ ADUs, and is essentially A/D saturation (32,767 ADUs) for the Ford CCD using the default gain. The TI upper limits can be exceeded when on-chip summing is in use, but caution is advised since the degree of summing varies.

The CCD detector will not be damaged by normal room light. You can safely enter the spectrograph room to cover or uncover the spectrograph optics with the lights on. Do not enter the room with a light during an integration as the CCDs suffer from some degree of persistence after exposure to high light levels.

3.3 Dewar Design and Maintenance

The CCDs are mounted in KPNO designed and manufactured universal dewars. The design of these dewars is such that they can be used in any position due to the arrangement of fill and vent tubes. Approximate LN2 hold times are 12 hours. The dewar should not be allowed to warm up (run out of LN2) during the time it is on the spectrograph. The mountain Technical Assistants will normally fill the CCD dewar with LN2 twice a day, in the morning and in the evening just before dinner.

The dewar should be filled in the following manner:

1. Unscrew the brass cap on the filler port.

Spectrum Widths for Camera 6 – Decker Plate 1						
Decker	Stellar (mm)		Comparison (mm)			
	Small Col.	Large Col.	Small Col.		Large Col.	
			Inner	Outer	Inner	Outer
1	13.52	9.17	14.88	25.09	10.10	17.02
2	9.54	6.47	10.56	21.05	7.16	14.28
3	4.76	3.23	5.80	16.26	3.94	11.04
4	3.38	2.29	4.43	10.69	3.01	7.26
5	2.35	1.59	3.39	9.68	2.30	6.57
6	1.65	1.12	2.02	3.70	1.37	2.51
7	1.17	0.80	1.53	3.18	1.04	2.16
8	0.84	0.57	1.13	2.85	0.76	1.94
9	0.57	0.38	0.90	2.59	0.61	1.76
10	0.33	0.22	0.67	2.33	0.45	1.58

Table 13: Spectrum widths for camera 6 – decker plate 1

2. Connect the metal hose from the LN2 storage tank to the dewar filling port **finger** tight. Back-off the fitting 1/2 turn and tighten only after the fitting is cold. This prevents the fitting from contracting tightly around the filling port and permits easy removal.
3. Open the valve on the storage tank, pressurizing with dry N2 if necessary. The dewar should be filled rapidly to prevent freezing the seal around the filler port.
4. When the LN2 starts spraying out the vent holes, the dewar is full.
5. Remove the metal filling hose. If it has shrunk tightly around the filling port, either warm it up with a heat gun or wait a few minutes for it to expand. **DO NOT FORCE IT OFF WITH A WRENCH!**
6. Screw on the filling port cap. This is important to prevent the formation of an ice plug in the fill port.

The large gold box attached to the dewar contains video processing electronics, precision voltage references, precision clocks, and an electronic temperature controller.

The mounting of the CCD dewar to either camera 5 or 6 is accomplished by use of either of two mounting plates which attaches to a bracket on each camera. This mounting system allows rotation and motion perpendicular to the dispersion to facilitate spectrum alignment parallel to chip columns and proper centering. Centering in the direction of dispersion (selecting central lambda) is done by moving the grating under computer control.

Spectrum Widths for Camera 6 – Decker Plate 2				
	Small Set (mm)		Large Set (mm)	
Decker	Small Col.	Large Col.	Small Col.	Large Col.
1	0.358	0.234	5.142	3.369
2	0.295	0.193	2.621	1.717
3	0.232	0.152	2.100	1.376
4	0.190	0.124	1.684	1.103
5	0.153	0.100	1.347	0.883
6	0.126	0.083	1.090	0.714
7	0.105	0.069	0.884	0.579
8	0.090	0.059	0.705	0.462
9	0.068	0.045	0.568	0.372
10	0.047	0.031	0.468	0.307

Table 14: Spectrum widths for camera 6 – decker plate 2

3.4 CCD Control System

The CCD control system consists of an interface chassis, the CCD controller, and a Sun SPARC station computer. Associated with the computer are 2 1-gigabyte disks for data storage, an HP 1600/6250 bpi tape drive, an Exabyte 8 mm cassette drive, and a DAT unit. The data can be displayed and plotted on the SPARC station as it is obtained.

3.5 CCD Camera Dewar on Spectrograph Camera 5

Camera 5 is perhaps the most effective and versatile location for the CCD dewar on the coude spectrograph, as resolutions from 1.8 - 0.04 Å are possible. The large demagnification (6.3, small collimator; 9.4, large collimator) enables the use of a wider slit and yields narrower spectra on the chip than camera 6. This vertical demagnification is important since the fewer columns the spectrum falls on, the less likely the chance for a cosmic ray hit and the lower the final readout noise per resolution element. If on-chip summing is used, then the later limitation need not apply. Tables 5 and 11 give the various dispersions and resolutions obtainable with camera 5.

3.5.1 CCD Installation on Camera 5

The installation of the dewar is best accomplished with two people as the dewar is moderately heavy (~45 lbs.). The dewar may be mounted to the removable mounting plate either with the plate on the camera bracket or off. In either case the screw-on shutter cap must be removed. The use of CCD dewars other than TI5 will require removal of the shutter assembly and installation of a special modified shutter mount. This allows unvignetted use of large CCDs, but requires a normal shutter be mounted just below the slit to control integrations.

Coude Camera Performance Using CCDs					
		Camera 5		Camera 6	
	Grating	blue(order)	red(order)	blue(order)	red(order)
reciprocal dispersion (Å/mm)	A	4.7(3)	7.0(2)	1.4(3)	2.1(2)
	B	9.9(3)	14.8(2)	2.8(3)	4.2(2)
	C	7.8(2)	15.7(1)	2.2(2)	4.4(1)
	D	3.8(2)	7.6(1)	1.1(2)	2.2(1)
	ECH	1.2(134)	1.8(89)	0.32(134)	0.51(89)
resolution(Å) (for 2.5 pixel line width, Ford CCD, 0.015 mm pixels*)	A	0.18	0.26	0.05	0.08
	B	0.38	0.55	0.10	0.15
	C	0.29	0.59	0.08	0.16
	D	0.15	0.29	0.05	0.08
	ECH	0.044	0.069	0.012	0.019
spectral coverage (Å) Ford CCD (3072 pixels)	A	215	322	61	96
	B	453	680	130	192
	C	361	722	100	200
	D	173	349	46	100
	ECH	54.0	84.5	14.7	23.0
~integ. t (sec) for S/N=100 (feed tel.) (V=6.0)	A	450	300	1500	1000
	B	200	150	600	300
	C	300	400	900	400
	D	500	300	2000	1000
	ECH	1800	900	3x3600	

*A TI 800 x 800 CCD is available for slightly better 2.0 pixel resolution, but less spectral coverage.

Table 15: Coude camera performance using CCDs

The orientation of the dewar on the mounting plate is with the electronics box **up** (spectrum parallel to rows, F3KB). If it is desired to have the spectrum parallel to rows with the TI5 CCD, the dewar mount rotation ring must be rotated counter-clockwise until it hits the other stop before mounting the dewar. Secure the dewar with the **long** stainless, 10-32 screws provided in the plastic bag always kept with the dewar shipping box. If the mounting plate is removed from the bracket, it must next be mounted back on the bracket and secured with the large captive screw on each corner.

The interface chassis should be mounted on its stand behind the dewar. **Always make sure that the interface power supply and controller main switches (under protective covers on controller rack) are off before attaching or removing cables from the interface box or dewar.** Cable up the interface box, but not the dewar. Turn on the interface power supply and check all of the voltages displayed on the interface chassis. If

CCD Characteristics		
	F3KB	TI5
cols x rows	3072 x 1024	800 x 800
pixel size (mm)	0.015	0.015
dimensions (mm)	46.1 x 15.4	12.0 x 12.0
gain (e ⁻ /adu)	3.0*	4.3
readout noise (e ⁻ rms)	8	8**
linearity (e ⁻)	170,000 @0.10%	36,000 @0.05%
dark current (e ⁻ /hr/pix)		1
radiation event rate/hr		low
*minimum value; adjustable		
**without preflash		

Table 16: CCD characteristics

they do not agree to within a few tenths of a volt to the nominal values, electronics support personnel should be called to make adjustments. Cable up the dewar to the interface chassis. Again, be sure that all of the voltages are proper before starting to cool the dewar. Section 3.3 may be consulted for instructions on filling the dewar with LN₂.

3.5.2 Alignment of CCD Camera Dewar on Camera 5

Once the CCD dewar has been installed, the following procedures are used to insure proper alignment, rotation, and focus of the spectrum on the chip.

1. **Set nominal height and focus.** Set the dewar mount vertical height and camera focus adjustments to their nominal values: Approximate values may be found on a card on the camera or check the observing log for recent values. The vertical height clamp must be released before setting. This is a large socket head bolt just below the vertical height readout.
2. **Check vertical height.** Using a small stellar decker and the quartz lamp, take a spectrum using the command **test** to check the vertical height of the dewar. The position of the spectrum on the chip can be determined by using the **implot** task to plot a cross-section of the spectrum. The difference between the spectrum position and the desired position can be noted and the dewar moved vertically with the aid of the vertical height dial indicator (1 division = 0.01mm). When the spectrum is oriented along rows the height adjustment works as follows: For F3KB and TI5, if the spectrum is too low on the chip, the dewar should be raised (increasing numbers on dial indicator). The best areas cosmetically might be determined from the *CCD Characteristics Manual* kept at each telescope. When using dewars other than these, consult with your instrument assistant for proper placement of the spectrum on the CCD.

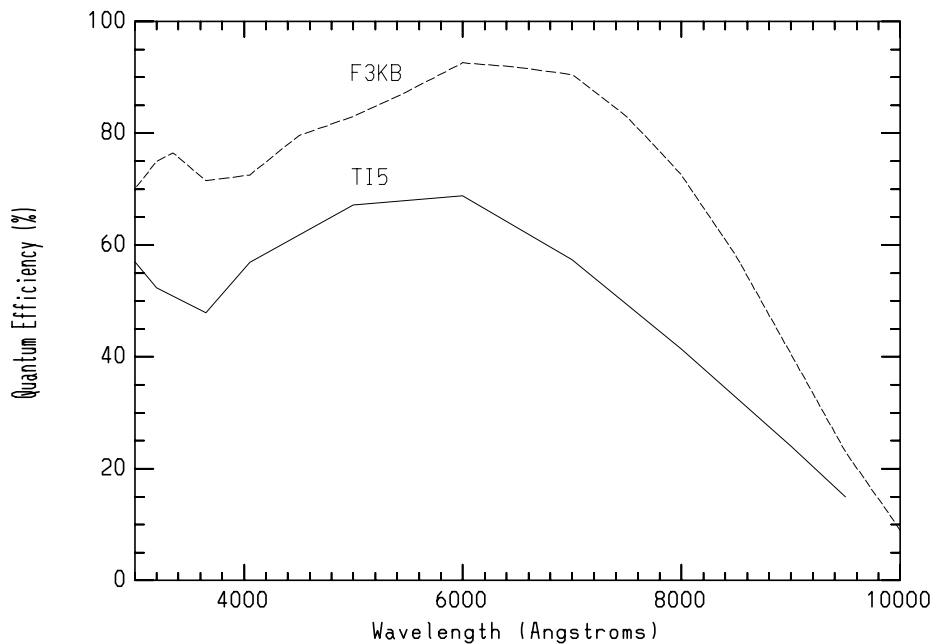


Figure 4: CCD Quantum Efficiencies.

- Adjust dewar rotation.** Once the spectrum is falling more or less in the desired region of the chip, it may be useful to reformat the CCD to be a narrow strip of about 50 - 100 rows or columns centered on the spectrum. This will reduce disk usage and readout time. Even with the two-dimensional echelle format it may be possible to reduce the width of the chip perpendicular to the dispersion somewhat. Type **detpars** to edit the readout parameters.

The rotational alignment may be checked by **splotting** one end of the spectrum, expanding around the profile, and using the “k” key on each side of the profile baseline to measure the position. Then overplot the other end of the spectrum and measure again. If the alignment is off by more than few tenths of a pixel, the dewar can be rotated using the rotation micrometer on the dewar mounting bracket.

First, loosen the rotation clamping screws $\sim 1/2$ turn. Assuming the order(s) are parallel to rows, if the upper end of the spectrum is shifted positively with respect to the lower end, then the dewar must be rotated with the rotation micrometer:

F3KB: clockwise 0.05 mm/pixel

T15: clockwise 0.18 mm/pixel

1 mm on micrometer = 2 revolutions. Note that if the micrometer is turned to larger values, the dewar will have to be manually rotated to bring the rotation stop against

the micrometer.

4. **Adjust focus.** The last step in preparing the spectrograph for observing is the final focus. Using a narrow slit (≤ 100 microns, camera 5; ≤ 50 microns, camera 6), the same decker used for the rotational alignment, and a comparison lamp suitable for the wavelength region of interest, obtain a series of spectra which bracket the position of best focus. A typical focus step size for moving the number 5 camera mirror (sphere) is 0.05 mm as read on the dial indicator. The comparison spectra may be plotted using the **splot** task with the line or column number given from the display window. If the spectrum is parallel to columns, the plot can be obtained by specifying the *disparis* parameter as “2” in the **kpnocoude** or **echelle** package parameters. Now one can expand around suitable lines and use the “k” key to fit gaussians to the line profile to obtain the FWHM. More than one comparison line should be used since the undersampling may cause some fluctuation in apparent line width.

Another useful tool for focusing is the SPECFOCUS task. EPAR SPECFOCUS and set the number of spectral regions desired and the upper and lower slit boundaries. Now type SPECFOCUS *image name* and plots will be generated showing the FWHM of the autocorrelation profiles for the regions designated. The task can also be run on a series of focus images. Some skewing of the results might occur if strong cosmic rays or hot columns are present.

The spectrograph camera focus is somewhat sensitive to wavelength; observers working in the red and blue may wish to check the focus at different spectral regions. It has been found that with the red corrector, the focus at 4500Å is about 0.12 mm higher than the focus value at 6500Å. A focus change may also be required if filters of different thickness are used at different wavelengths. If the copper sulfate filter is used for example, the camera focus will shift approximately -0.25 mm, compared to the focus with one of the 2 mm thick order separation filters.

After running through the focus and selecting the setting that minimizes the value of FWHM, set the camera focus and recheck. The focus setting and FWHM values should be recorded by the observer for reference as subsequent plots will erase the screen. The FWHM of a comparison line should be 2.0 - 3.0 pixels for the Ford CCD and 1.5 - 2.0 pixels for the TI CCD. The Ford chip will yield narrower line profiles in the red than the blue.

3.6 CCD Dewar on Spectrograph Camera 6

Camera 6 may be used with the CCD when resolution higher than ~ 0.20 Å is needed. The echelle/grism combination on camera 5 may be more advantageous however, due to the higher demagnification.

An image slicer is available for use on camera 6 and may be useful for certain types of observing (see §3.1 for dimensions). Each of the 10 output slices (0.04 mm x 0.50 mm) will have the dimensions given in Table 17.

Projected Image Slice Dimensions on Camera 6		
	large collimator	small collimator
projected height	170 μ	260 μ
projected width	13 μ	21 μ

Table 17: Projected image slice dimensions on camera 6

While the slicer may improve the total throughput, the image will be spread up to about 15 times as wide on the chip perpendicular to the dispersion. On-chip summing can be used to decrease the number of rows or columns involved, but “cosmic ray” hits will be increased by a factor of 15 also. This may not be serious for short exposures of brighter objects where high S/N or high time resolution is needed. Since typically 2 or 3 spurious events occur per spectrum per hour, 30 - 45 may occur during the same time with the image slicer. Please discuss these matters with your instrument assistant to decide upon a suitable mode of on-chip summing with the image slicer.

Preparations for use of the image slicer are the same as described for the slit below. After alignment is finished, the slicer is carefully inserted in the slots above the slit and the slit opened to at least 500 μ . The camera focus should now be decreased by 2.0 mm (small collimator) from its value with the slit, and checked with a comparison exposure. Note that the acquisition TV front lens will also have to be refocused to compensate for the slicer height.

3.6.1 Installation of CCD dewar on Camera 6

Since the dewar is mounted on camera 6 looking upwards, it must be attached to the dewar mounting plate before being inserted into the camera 6 dewar mounting bracket. The dewar should be attached to the mounting plate with the electronics package pointed opposite the rotation micrometers, as on camera 5. Be sure to use the **long**, stainless, 10-32 screws to attach the dewar to the mounting plate.

The next step is best accomplished with two people as the combined weight of the dewar and mounting plate is ~ 75 lbs. The dewar and mounting plate must be rotated so that the dewar is looking up and the electronics package facing south towards the number 6 camera mirror. The mounting plate can now be slid into the guides on the camera 6 mounting bracket and clamped with the 4 large, captive screws in the corners of the mounting plate.

The interface chassis can now be mounted on the stand that sits on the floor grate next to camera 6, oriented to allow the short cables to reach between the dewar and the interface chassis. **Always be certain that the interface power supply and controller main switches (under protective covers on the controller rack) are off before attaching or removing cables from the interface box or dewar.** Cable up the interface box and check the voltages as in section 3.5.1. After switching the power off, cable the dewar to the interface chassis.

3.6.2 Alignment of the CCD Camera Head on Camera 6

Alignment and focusing of the CCD on Camera 6 is basically the same as on camera 5, with the added complication of the flat pick-off mirror which deflects the beam downward into the dewar.

1. Set the flat mirror vertical height to 30.00.
2. Set the dewar mount vertical height micrometer and camera focus to their nominal values: recent values may be found on a card attached to the camera or in the coude spectrograph CCD logbook. The small flat pick-off mirror should not be tampered with as it has been preset and clamped in place.
3. The dewar rotational alignment and vertical height can be adjusted as in §3.5.2, steps 2 – 3.
4. The final focus can now be determined using a narrow slit (<50 microns), and a comparison lamp suitable for the wavelength region of interest. The focus procedure discussed in §3.5.2, step 4 may be used. A typical focus step size for moving the dewar mounting assembly is 0.20 mm as read on the dial indicator. After running through the focus and selecting the setting that minimizes the value of FWHM, set the camera focus and recheck. Note that grating D will not give line widths $<\sim 3$ pixels (TI CCD) since its theoretical resolution is only 0.02\AA . The convolution of this resolution with the dispersion (0.03\AA per pixel, red), and camera resolution ($\sim 0.04\text{\AA}$) cannot yield an image smaller than ~ 3.4 pixels (TI CCD). The echelle grating also will not yield line widths less than about 3 pixels (TI) due to the long camera focal length actually resolving the argon and thorium lines. In fact the argon lines may be noticeably broader than the thorium lines due to the smaller mass of the argon atoms.

4 Observing Philosophy

In principle, observing with the CCD detector is just a matter of integrating long enough on a given object until the desired signal/noise ratio is obtained. Figure 5 shows theoretically obtainable s/n ratios vs. count rates (ADU's) assuming a readout noise value of 12 e^- per pixel for TI 5 (with preflash) and 8 e^- per pixel for F3KB. Note that the values given on the graph are per pixel and there are usually several pixels perpendicular to the dispersion to extract. Therefore the final signal to noise obtained is higher than that obtained from just the count rate of the maximum intensity pixel. While dark count rates are usually negligible, radiation event spikes will show up at a minimum rate of about 1 - 2 per hour for TI5, and 4 - 8 per hour for F3KB, per spectrum.

4.1 Observing Procedures

Once the detector has been aligned and focused (§3.5.2 & §3.6.2), the required calibration exposures should be made. An initial set of calibrations can be made just before dark, and

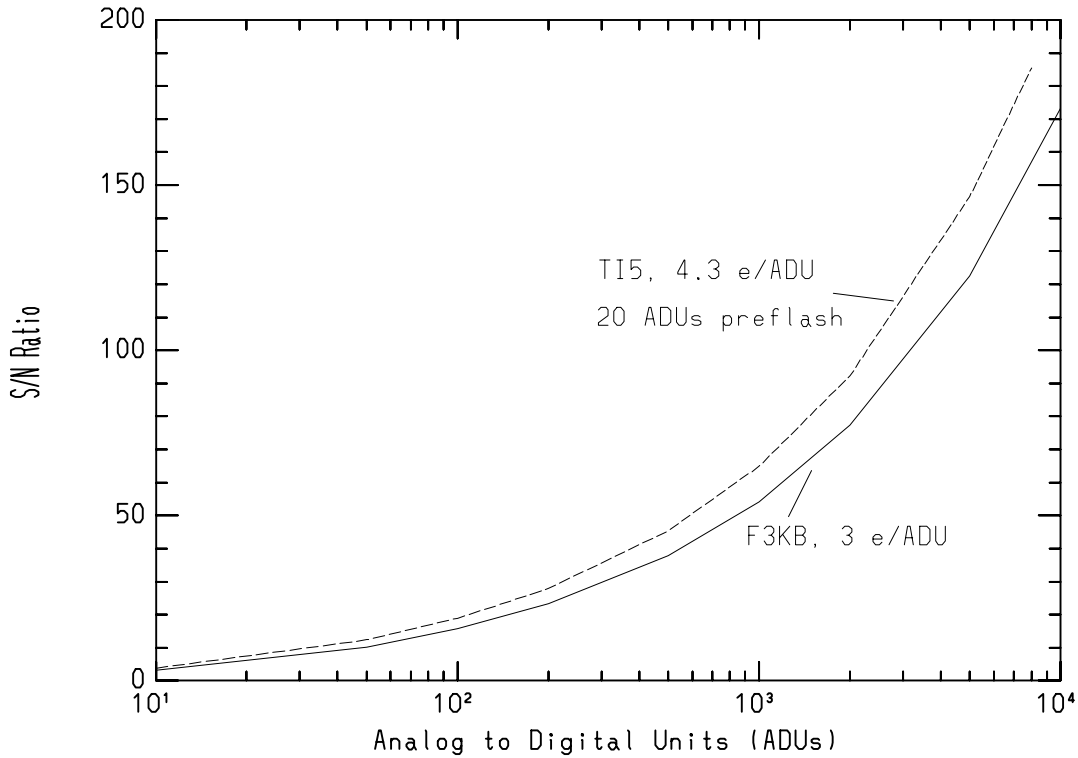


Figure 5: Theoretical S/N Values per Pixel for CCDs.

additional frames secured at convenient times during the night. It is important when trying to achieve high signal to noise ratios to secure flat fields at least three times during the night as the chip position does change slowly. The data can then be reduced with the appropriate set of flat-fields according to the time of exposure. Be sure to repeat all of the calibrations each night as small changes of dewar position may occur when the dewar is filled with LN₂. If accurate radial velocity measurements are being made, comparison exposures should be obtained at least once an hour to map small pixel shifts throughout the night.

Before the calibration exposures are made the observer must decide whether to use on-chip summing or not (see §3.2). On-chip summing will be more advantageous on camera 6 than on camera 5. This is due to the larger spread of light perpendicular to the dispersion on camera 6. If on-chip summing is selected, all calibration exposures must be made in that mode as well as the object exposures.

Comments are given below on the various types of pictures:

zeros A DC offset is added to the overall signal from the CCD to insure no negative data. This “pedestal” level (a few hundred ADUs), formerly known as “bias” has no particular significance other than it should be stable. Obtain 10 - 20 per night. They can be spaced

throughout the night or split between beginning and end of night. Zero exposures are important for the TI CCDs where preflash is generally used, but may not be necessary for some of the TEK CCDs where the bias level is very uniform. In this case one could use the overscan or the region on each side of the spectrum to subtract the bias level.

darks If relatively short exposures are planned (1 hour or less), there is probably no need to obtain dark exposures. Obtain a couple 10 or 20 minute darks just to check on dark current and look for any hot pixels. If a hot pixel is seen, it may be possible to move the spectrum vertically to higher or lower column numbers to avoid it.

flats Obtain a total of at least 10 times (and preferably more) the number of ADU's compared to the count rate of your most intense spectrum, using a decker large enough to be wider than object spectra. To avoid possible non-linearities, no spectrum (object or FLAT) should exceed 8000 ADUs with a TI CCD. See §3.2 for exceptions. For example, if your spectrum has an intensity of 5000 ADUs, obtain at least 10 FLATS with 5000 ADUs each. These exposures may be split between the beginning and end of the night or grating setting. If on-chip summing is in use, the spectrum intensity may exceed the above limits, but since the amount of summation varies, caution is advised.

comps Obtain at least one per data set. More may be useful if accurate radial velocity measurements are to be made. Wavelength shifts on the order of a few tenths of a pixel have been measured over a period of hours.

observe Main observing word. Again, be careful not to exceed ADU limits discussed above per pixel unless on-chip summing is in use. Any of the above data types can also be obtained using this command.

Carefully filling out the logbook on the logsheets provided will make subsequent data reductions easier. Please leave the originals in the notebook; copies can be made in the administration building for taking home.

5 Data Reductions

Complete calibration and extraction of coude CCD data may be done at the telescope if desired using the packages available on the SPARC station. Be sure to record the raw data on tape before using any of the CCDPROC routines as they alter the data in place. After initial debiasing, flat-fielding and trimming, the spectra may be extracted and wavelength calibrated either step by step, or automatically using the IRAF tasks **doslit** and **dofibers**. The manuals *A User's Guide to Reducing Slit Spectra with IRAF*, and *A User's Guide to Reducing Echelle Spectra with IRAF*, may be consulted as illustrations of procedures.

A variety of tape formats are available for taking spectra away from Kitt Peak. Please discuss your requirements with an instrument support person before or during your run.

6 Computer Operation

In the fall of 1991, the long-standing FORTH systems were replaced with an IRAF based acquisition system (ICE - Iraf Control Environment) running on Sun workstations. This enables the observer immediate access to the many IRAF routines for data reduction and analysis. This section is not intended to be a detailed description of the ICE, but a concise summary and quick reference. For more details see *An Observers Guide to Taking CCD Data with ICE* by Massey et al., and the references listed therein.

6.1 Logging In, Initializing ICE, and Logging Out

The SPARC station currently running ICE at the coude spectrograph is named indigo. The login name is “feed” and the current password can be found on the front of the terminal. After logging in a menu of different applications is presented from which “ICE” is usually appropriate. This selection will start an Acquisition window, a Reduction window, and an Ximtool window. CCD data acquisitions commands should only be issued from the left (acquisition) window.

It is good practice to initialize ICE to its default values and delete all existing files at the beginning of an observing run. First log out of IRAF in all windows and then type **obsinit** in any window with the Unix prompt (%). Answer the questions as they appear and then log out of the workstation completely (see below) in order for the changes to take effect.

Exiting the workstation is done by first typing **logout** of each XGTERM window. Next move the mouse to a blank area of the screen, hold down the right mouse button and select “exit”.

6.2 Parameter Sets

All IRAF tasks are controlled by parameter sets edited by typing **epar taskname**

For example, to edit the task **wfits**, type **epar wfits**

and use the up and down arrows to position the cursor at different parameters. Merely type the desired parameter in followed by the **return** key to store the new value. Use **Ctrl-Z** or **Ctrl-D** (depending on the setup with **obsinit**) to save the new parameter set.

There are three parameter sets that control or modify the data taking process and should be modified to suit the observing needs. These parameter sets may be edited by just typing the name of the parameter set, unlike the discussion above.

detpars Controls the CCD readout parameters such as format, binning, and gain.

obspars Specifies image naming and other diverse header information.

telpars Most parameters supplied automatically by TCP/CCD link. If the TCP computer is down, set *telname* to “test”; otherwise it should be “kpcfd”.

There is one other parameter set, **instrpars**, which is currently not actively linked to the spectrograph; some of the parameters may be useful for later reductions.

6.3 Data Acquisition Tasks

observe Main observing task; prompts for image type, exposure time and title.

zeros Starts sequence of bias exposures; prompts for number.

objects Starts sequence of object exposures; prompts for number and exposure time.

flats Starts sequence of flat-field exposures; prompts for number and exposure time.

darks Starts sequence of dark exposures; prompts for number and exposure time.

tests Start a test exposure that will overwrite any previous image named "test".

mores Starts a sequence of **observes** identical to the previous one.

p Can be used to pause the integration clock and close the shutter.

r Used after **p** to restart the integration clock and open the shutter.

S Can be used after **p** to terminate an exposure at any time.

A Can be used after **p** to terminate an exposure with no data written to disk. The exposure counter will not be updated.

6.4 Image Tasks

imcopy Copies an image, or subraster of an image, to another image.

imrename Renames an image.

imdelete Delete an image or images.

imheader List image headers.

hedit Edit the header parameters of an image.

hselect List specific items from the image headers.

imhist Plot a histogram of the pixel values in an image.

imstat Print statistics on an image.

implot Interactively plot columns and lines of an image.

splot Interactively plot lines or columns of an image with spectral analysis tools.

6.5 Tape Tasks

allocate Allocate a tape drive; e.g.: **allocate mta** or **allocate lapis!mta**.

deallocate Deallocates a tape drive.

wfits Write a FITS format image to tape or disk.

rfits Read a FITS format image from tape or disk.

mtexamine Examines a magnetic tape.

6.6 Miscellaneous Tasks

diskspace Check capacity of disks.

dir List files in current directory.

display Display an image in the IMTOOL window.

files Generate a list of files for taping or other reductions.

ccdinfo List all CCD parameters such as gain, format, binning, etc.

7 The Coudé Feed Telescope

The coudé feed telescope consists of a 0.9 m off-axis, paraboloidal, image forming mirror, fed by a 1.5 m alt-azimuth mounted flat mirror. Due to this mounting configuration, observations north of +70 degrees will suffer from vignetting (figure 6). The flat mirror is moved under computer control either via push button controls on the operator console, or through the computer terminal. Various utility commands are available for storing coordinates, finding ephemeris stars, etc. These are discussed in the following sections.

7.1 Open-up Procedure

1. Go up on the roof, inside the shed, and remove the mirror cover from the flat and store in the wall holder. *Caution: Never remove or install the mirror cover with the shed moved back.* Open the garage door by pushing the button on the side of the light switch. At the front of the housing push the OPEN button to roll the housing back. Also open the hatch cover at the top of the tunnel. **Note! Observers are currently not allowed on the roof.** The Observing Technician or 2.1m telescope operator should be notified to open the shed and tunnel.
2. Push on the main power button at the slit head control panel.
3. Take the covers off the number 3 mirror, slit head, the slit end of the TV-zoom lens system, and finder flat mirror.

4. Check that the high voltage pot is turned down all the way (CCW) on the slit viewing TV. Turn on the TV camera with the switch on the camera power/controller unit. Turn on the the two monitors inside the observing room, the two distribution amplifiers, the digital TV memory and the guider interface.
5. If not already logged in on the feed computer (lisa), do so by logging in as “tcp” using the password posted on or near the terminal. If the computer is in some other unknown state, see *A Quick Guide to the New Coudé Feed Control System* (hereafter known as Telescope Manual).
6. When you are ready to unstow the telescope, click the left mouse button on the “open/stow” button in the main telescope control (TC) window. Another subwindow will open showing the status of the telescope and its various parts. Click on the “open” button to unstow the telescope. A comment will appear in the status box in the TC window when the telescope is ready.

7.2 Setting the Grating

Open the grating window with the grating button at the top of the TC window. Select the appropriate camera, grating and collimator with the respective buttons. Now the order and wavelength can be entered on the appropriate line, activated with a carriage return or clicking the left mouse button on the line. The AC power switch on the slit-head panel should be on. Before clicking on the “set grating” button, turn on the grating drive switch in the console room rack. If after checking the wavelength centering it is found to be not quite right, the “nudge” button can be used to move up or down the specified amount. Switch off the power in the console room rack when finished as the grating can move slightly with the power on.

7.3 Finding Stars

Setting the coudé feed telescope is accomplished usually through the the utilities provided in the Star Cache (SC) window. While coordinates could be entered one at a time using the “edit next” button or the command line emulator (target), it is most efficient to use the various star caches and utilities provided for them. Caches exist for Almanac Bright Stars, the Yale Bright Star Catalogue, and SAO stars among others, as well as any the user may have in the archive or creates. A nearby bright star may also be searched for near the current telescope position for pointing checks. Your instrument assistant can demonstrate most aspects of this system in about 5 minutes, and detailed instructions are given in the Telescope Manual.

It is good practice to initially set on an Almanac star within about one-half hour of the meridian and near the celestial equator to check the telescope pointing. If necessary, the “Z” button can be used to reset the coordinate system.

7.4 Guiding With the DTI-21 Leaky Guider

The guider allows complete freedom from manual guiding during an integration. When the guider is first turned on, the cursors must be activated by pushing the upper right button on the guider control box. Tap the button until the box and cross are both in a dim mode and then they may be moved together with the direction buttons to center the guide box over the slit or fiber. The position of the box may still be adjusted anytime before or while guiding. To observe using the guider, a star is placed in or near the cursor box, the guider software enabled (click on the “guider” button in the TC window), and the integration started. The guider is disabled by clicking the “guider” button again, but it will be automatically disabled anytime the “go there” button is clicked.

A zoom lens is mounted in front of the ISIT TV and may be controlled with the buttons in the console room or at the slit-head panel. The AC power switch on the slit-head panel must be on. The zoom lens is useful for controlling the size of the slit image with respect to the guide box and for achieving a larger field of view. The position of the stellar image on the TV monitor will generally change with zoom value, and the guide box will have to be repositioned.

7.5 Typical Observing Procedure

1. Move the mouse pointer to the list of star caches in the box at the upper left corner of the SC window. Click twice on the name of the cache you want to list. The contents of the cache will appear in the display area.
2. Click the mouse on the desired star, click on “send next” to send the coordinates to the TC window. A double click on the star entry will send the coordinates directly to the TC window.
3. After making sure the “next” box is the active one, click on the “go there” button in the TC window.
4. When slew is complete, center the star on the slit and click on the “guider” button to turn the guider on.
5. Start the CCD integration.

For subsequent objects, step 2 can be done while the current integration is in progress, and step 3 as soon as readout commences.

7.6 Feed Telescope Shutdown Procedure

1. Turn down TV high voltage control pot and switch TV, monitors, guider interface, and guider off.
2. In the TC window, click on the “open/stow” button, then click again on the “stow” button in the window that pops up.

3. After the telescope returns to stow position (red limit lights on), push **SYSTEM POWER OFF** button on coudé feed slit head control panel.
4. Up on the roof, stow the shed over the mirror by pushing the **CLOSE** button on the panel at the south edge of the roof. Close the garage door and replace the mirror cover, using care not to damage the mirror surface while keeping the orientation of the cover with the arrow up. Close the tunnel hatch cover. **Note! Observers are currently not allowed on the roof. The 2.1m telescope operator should be notified to close the shed and tunnel.**
5. Replace all covers over optics in spectrograph room, at slit-head, TV and number 3 mirror.
6. If desired, log out of the telescope terminal by holding down the right mouse button in a clear part of the screen, drag the mouse arrow down to the “exit” line and release. Click on the appropriate message in the “confirm” window that pops up.

7.7 Coudé Image Rotator

An image rotator/derotator is available by turning the hand-crank until it reaches its stop (fig. 2a). Power to the rotator is provided through the switches on the slit-head panel for slew and track.

The image rotator, having been built originally for the 2.1 m telescope, will not work without manual intervention for the feed telescope. This is due to the feed’s alt-az mount which results in non-uniform rotation of the field. Programs are available to calculate the required angle so that the rotator can be manually adjusted every few minutes to keep the slit projected to a particular angle on the sky.

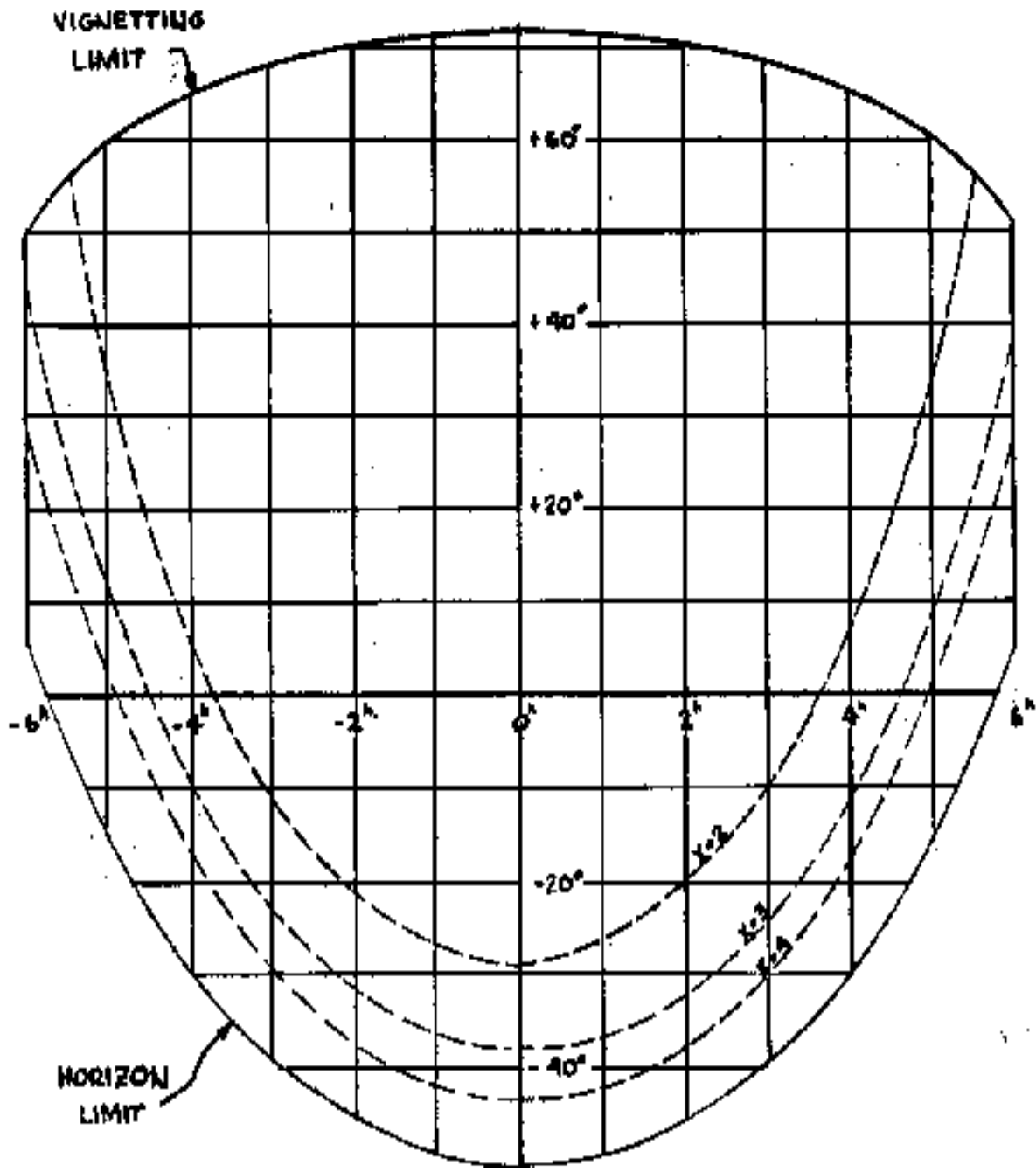


Figure 6: Sky Coverage for Coude Feed.