NIRSPEC

UCLA Astrophysics Program **U.C. Berkeley** **W.M. Keck Observatory**

Don Figer

May 30, 1996

NIRSPEC Optics Design Note 17.00
Gratings Design and RFQ

1. Introduction

This note contains the designs and RFQs for the echelle and cross-disperser gratings. I have included RFQs for grating replication as well as substrate fabrication. In contrast to most of the other optics, we are designing all aspects of the gratings, including the optical substrates, mechanisms, and motion control hardware. In principal, then, this note will cover a greater variety of issues than the others because it will contain sections concerning the mechanical design of the substrates. The echellograms are given in NODN1900.

The substrate designs, i.e. locations of screw holes, depend upon the mechanism designs, so this note will be updated later when the mechanical designs for the grating mechanisms are complete. As it stands now, we have preliminary sketches of the echelle mechanism (NCDN1101), and two preliminary design concepts for the cross-disperser mechanism. Because of their preliminary nature, these designs do not give hard constraints on the mechanical tolerances for the substrates. For instance, we do not know the exact tolerances for the substrate sizes, the required parallelism, or the exact locations (or sizes) of the mounting holes and tabs. Although our specifications are not known exactly, we can place rough tolerances on most parameters.

2. Echelle Parameters

The grating optical parameters are: groove density, blaze angle, and size. The groove density controls which wavelengths will be imaged in a given order. The blaze angle only impacts the efficiency as related to the geometry of the beams and the grating (Figure 1). The size needs to be large enough to accomodate the beam for the full range of grating tilt angles. A thorough discussion of resolution, efficiency, and other important issues can be found in a broad range of literature: NIRSPEC proposal document, PDR & CDR documents, “Spectrograph Format” by James Graham, the Diffraction Grating Handbook by Spectronic, Inc., and Feynman’s Lectures on Physics. For the purposes of this document, I will review the grating equation and then give the grating parameters for our gratings.

The grating equation is given in equation 1. The angles are shown in Figure 1. The out-of-plane angle, γ, is measured with respect to a vertical axis (in the plane of the page) in this figure. In our instrument, $\gamma = 5°$ to allow the cross-disperser to intercept the beam without colliding into the collimator beam. For a given order, the output angle, β, will change with λ, i.e. the grating produces a wavelength dispersion in the output beam. The relationship between wavelength and output angle can be changed by tilting the grating so that the input angle, α, changes. In this way, the wavelength falling at the center of the array can be changed. This principle can be used to adjust the wavelength map in both the primary and cross-dispersed directions.

$$\begin{aligned} m\lambda T &= (\sin\alpha + \sin\beta)\cos\gamma, \\ \textit{where, } m &= \textit{order number}, \\ \lambda &= \textit{wavelength in } \mu m, \\ T &= \textit{groove density in } \frac{\textit{lines}}{\mu m}, \\ \textit{and } \alpha, \beta &\textit{, and } \gamma \textit{ are described in the text.} \end{aligned} \tag{1}$$

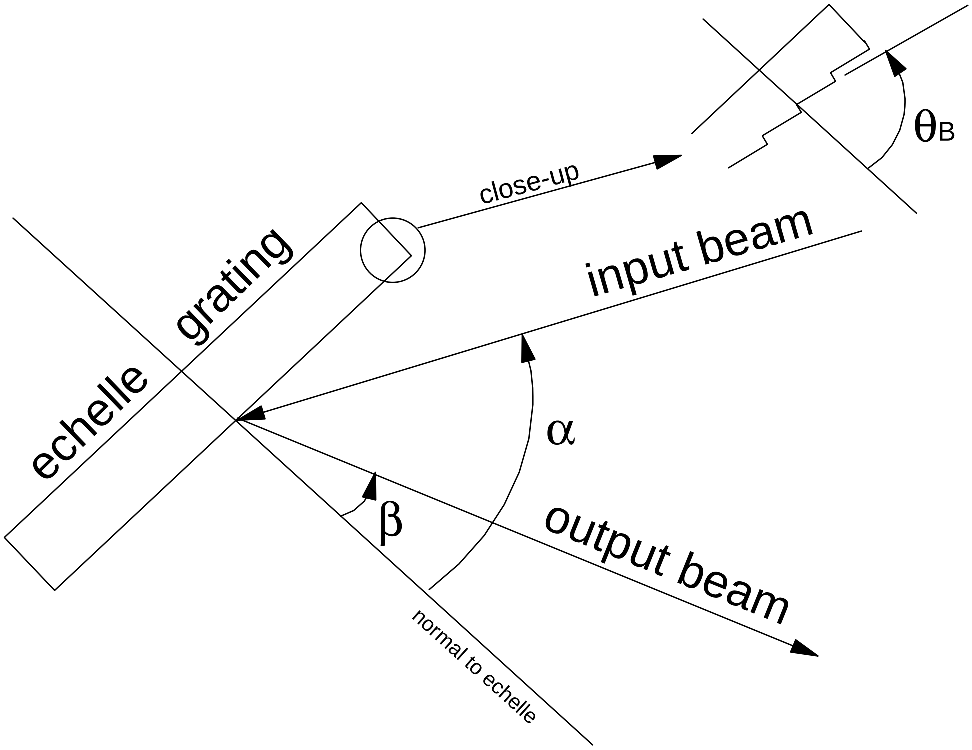

Figure 1. Side view of echelle grating. The general case shown does not assume any special relationship between the input (α), output (β), and blaze angles (θ_B). The close-up shows the grooved surface and adhesion layer as they sit on top of the bare grating substrate.

The resolution is related to the grating equation via equation 2. This definition of resolution assumes that two nearby spectral lines will be “resolved” if they are separated in wavelength by more than $\Delta\lambda$. It is important to realize that other definitions of resolution may be valid given a particular observational goal. For instance, the velocity centroid of a line may be measured to within $\Delta\lambda_{res.elt}/20$ given proper sampling. Also, it is possible to fit a suspected blend of lines, each separated by $\Delta\lambda$, provided we already know that they are there. In any case, we will refer to resolution as R in equation 2.

$$\begin{aligned} R &= \frac{\lambda}{\Delta\lambda} = \frac{\lambda}{\Delta x}\frac{dx}{d\lambda}, \\ \text{where, } \frac{dx}{d\lambda} &= \text{linear dispersion in } \frac{mm}{\mu m}, \\ \Delta x &= \text{width of the resolution element at the focal plane.} \end{aligned} \tag{2}$$

The linear dispersion, dx/dλ, is given by multiplying the angular dispersion by the effective focal length of the camera, as shown in equation 3. The output angle, β, varies across the focal plane, so the linear dispersion will also vary. Also, F_{cam} might vary across the format due to the distorting characteristics of the optics. In general, then, the linear dispersion will be a function of position in the focal plane.

$$\begin{aligned} \frac{dx}{d\lambda} &= F_{cam}\frac{d\beta}{d\lambda} = \frac{mTF_{cam}}{\cos\beta\cos\gamma}, \\ \text{where, } F_{cam} &= \text{the effective focal length of the camera in mm.} \end{aligned} \tag{3}$$

Equations 2 and 3 can be combined to yield equation 4. If Δx corresponds to a fixed linear size at the focal plane, then the resolution will vary somewhat with β. However, sticking with our original definition for R, we must consider Δx to be the linear size associated with the slit image at the focal plane. This distinction is important because the slit image width will vary across the format due to the distorting properties of the grating.

$$R = \frac{\lambda}{\Delta x}\frac{mTF_{cam}}{\cos\gamma\cos\beta} = \frac{F_{cam}}{\Delta x}\frac{\sin\alpha + \sin\beta}{\cos\beta}. \tag{4}$$

A grating will distort an image by varying the plate scale at the focal plane along the axis of dispersion. This effect is shown in equation 5. Here, we differentiated equation 1 in order to get dβ/dα. The reason for this factor has to do with the fact that the grating induces a reflection which does not obey the standard law of reflection, i.e. it is not specular. This effect can best be seen in the Diffraction Grating Handbook from Spectronic, Inc.

$$\begin{aligned}\Delta x &= w\frac{d\beta}{d\alpha}\frac{F_{cam}}{F_{coll}} = w\frac{\cos\alpha}{\cos\beta}\frac{F_{cam}}{F_{coll}},\\ \textit{where, } w &= \textit{the slit width},\\ \textit{and, } F_{coll} &= \textit{the focal length of the collimator}.\end{aligned} \tag{5}$$

Combining equations 4 and 5 yields equation 6. Here, we see that the slit-limited resolution will be nearly constant across the format, barring any distortion due to the camera optics.

$$R = \frac{F_{coll}}{w}\frac{\sin\alpha + \sin\beta}{\cos\alpha}. \tag{6}$$

Equation 7 relates the resolution to the size of the collimated beam, the diameter of the telescope primary, and the angular width of the slit on the sky. It is important to realize that this resolution corresponds to a slit width and assumes that the slit is properly sampled at the focal plane.

$$\begin{aligned}R &= \frac{d}{D\Delta\theta}\frac{\sin\alpha + \sin\beta}{\cos\alpha},\\ \textit{where, } \Delta\theta &= \textit{angular extent of slit on sky},\\ d &= \textit{diameter of the collimated beam in the spectrograph},\\ \textit{and, } D &= \textit{diameter of the telescope primary}.\end{aligned} \tag{7}$$

We know from the scientific requirements that R - 25,000 and $\Delta\theta$ = 0.4O for the baseline configuration. We also know that the grating will give maximum efficiency for $\alpha=\beta=\theta_B$. Inserting these parameters in equation 7, and solving for d, we get equation 8. Of course, we would like d to be as small as possible because the beam leaving the slit is f/10, so the collimating mirror must have a focal length equal to 10 times d, and it must be placed at a distance from the slit equal to its focal length. So, the larger d is, the further away the collimator must be placed and the larger the instrument becomes. This line of argument would indicate that θ_B should be as high as possible.

$$d = \frac{DR\Delta\theta}{2\tan\theta_B} = \frac{242}{\tan\theta_B}\ mm. \tag{8}$$

There is not complete freedom to choose just any θ_B one may want. Spectronic, Inc. only make gratings with a few different θ_B. Also, by examining Figure 1, we can see that the grating size equals d/cosθ_B. Using equation 8, we find that the grating size = 242 mm/sinθ_B. This is actually just the minimum size of the grating to accommodate a fixed grating orientation. The grating will have to be a bit larger than this to allow for tilting the grating while still intercepting the full beam width. We can see that the grating will have to be at least 242 mm in ruled width.

There are only 3 possibilities for θ_B which give a grating large enough for our purposes, 63.5°, 75.0°, and 69.0°. From discussions with Spectronic, Inc., we know that the θ_B = 75.0° grating has a lower efficiency than the one with θ_B = 63.5°. It also only comes with T = 31.6 l/mm, a value which is higher than we would like, as we will see later. The θ_B = 69.0° grating only comes with T = 52.67 l/mm, well higher than what we desire. So, we chose the θ_B = 63.5° grating with T = 23.2 l/mm, although they do offer one with T = 31.6 l/mm. Given our choice, then, the beam size, d, is - 120 mm, and the long dimension of the gratings, the ruled width, will be at least 270 mm.

As stated earlier, we settled on a groove density of 23.2 l/mm. This parameter controls which wavelengths are found in the various orders. The right hand side of equation 1 is fixed by geometry. Inserting our choice of T then gives $m\lambda_{central}$ = 76.7. This condition is preserved for the central wavelengths of all orders. The free spectral range of a grating is λ/m. In order to just fit a free spectral range on the detector, equation 9 must be satisfied. For our camera, w'/p = 2.76, R - 25,000, and N = 1024. These parameters give m_{FSR} = 66 and $\lambda_{central}$ = 1.16 μm. For the 31.6 l/mm grating, these relations would give $\lambda_{central}$ = 0.85 μm, too low to be useful. If we wanted to match the free spectral range to the array in the K band, we would need a grating with T - 12 l/mm.

$$\begin{aligned} m_{FSR} &= \frac{Rw'}{pN}, \\ \text{where, } w' &= \text{slit width at focal plane}, \\ p &= \text{pixel size}, \\ \text{and, } N &= \text{number of pixels across array}. \end{aligned} \qquad \textbf{(9)}$$

3. Cross-disperser Parameters

The cross-disperser works in much the same way as the echelle (see Figure 1), except that the groove density is higher, the blaze angle is smaller, and it is arranged so that the grooves are orthogonal to the grooves on the echelle. In addition, there is no out-of-plane angle, γ, and the in-plane angle between the input and output beams, $*\beta\ !\ \alpha*$ is 50°. The cross-disperser can be used in two different modes, one where the echelle orders are spread apart on the array, and one where the echelle is replaced by a mirror, and the cross-disperser becomes the primary dispersing element. In either case, we can still use the equations derived earlier to describe how the cross-disperser will affect the beams.

Given that there must be an in-plane opening angle, the condition for maximum efficiency is met when $*\alpha \; ! \; \theta_B* = *\beta \; ! \; \theta_B*$. We can also use equation 6, where the desired resolution is about 2,000. We now have 3 equations and 3 unknowns, α, β, and θ_B. Solving, we arrive at α - 35°, β - ! 15°, and θ_B - 10°.

In the slit height direction, the focal length of the camera is about 405 mm. Using this, we can calculate the amount of spreading of the echelle orders caused by the cross-disperser. This will be dependent upon the cross-disperser groove density. This spreading will tell us exactly how much of the slit length is useful, or how long the slits should be. The distance between orders is shown in Table 1 for T = 75 l/mm.

We can see that the slit heights can be fairly small at the short wavelength end of our range. We will not want to choose just any cross-disperser order given a wavelength of interest even though it appears that the allowable slit height increases with order number. Each wavelength will have a preferred order due to efficiency considerations as stated above. The input and output beams should always bisect the blaze facet, as indicated for the parameters above. This relationship requires that $m\lambda_{central} = 4.2$. So, we will want to image wavelengths near 4 μm in first order, wavelengths near 2 μm in second order, and so on.

Table 1
Maximum Allowable Slit Height

m_e	$\lambda_{central}$ μm	Maximum Slit Height arcsecsonds			
		m(c)=1	m(c)=2	m(c)=3	m(c)=4
10	7.6532	131.8	263.3	395.7	537.5
11	6.9575	108.7	216.8	325.2	440.2
12	6.3777	91.2	181.7	272.2	367.5
13	5.8871	77.7	154.5	231.2	311.7
14	5.4666	66.9	133.1	198.9	267.8
15	5.1021	58.2	115.8	173.0	232.7
16	4.7833	51.2	101.7	151.8	204.1
17	4.5019	45.3	90.0	134.4	180.5
18	4.2518	40.4	80.2	119.7	160.8
19	4.0280	36.2	71.9	107.4	144.1
20	3.8266	32.7	64.9	96.8	129.9
21	3.6444	29.7	58.8	87.8	117.8
22	3.4787	27.0	53.6	80.0	107.2
23	3.3275	24.7	49.0	73.1	98.1
24	3.1888	22.7	45.0	67.1	90.0
25	3.0613	20.9	41.5	61.9	82.9
26	2.9435	19.3	38.3	57.2	76.6
27	2.8345	17.9	35.5	53.0	71.0
28	2.7333	16.7	33.0	49.3	66.0
29	2.6390	15.5	30.8	45.9	61.5
30	2.5511	14.5	28.8	42.9	57.5
31	2.4688	13.6	26.9	40.2	53.8
32	2.3916	12.8	25.3	37.7	50.5
33	2.3192	12.0	23.8	35.4	47.5
34	2.2509	11.3	22.4	33.4	44.7
35	2.1866	10.7	21.1	31.5	42.2
36	2.1259	10.1	20.0	29.8	39.9
37	2.0684	9.5	18.9	28.2	37.7
38	2.0140	9.0	17.9	26.7	35.8
39	1.9624	8.6	17.0	25.4	34.0
40	1.9133	8.2	16.2	24.1	32.3
41	1.8666	7.8	15.4	22.9	30.7
42	1.8222	7.4	14.7	21.9	29.3
43	1.7798	7.1	14.0	20.9	27.9
44	1.7394	6.7	13.4	19.9	26.7
45	1.7007	6.4	12.8	19.0	25.5
46	1.6637	6.2	12.2	18.2	24.4
47	1.6283	5.9	11.7	17.5	23.4
48	1.5944	5.7	11.2	16.7	22.4
49	1.5619	5.4	10.8	16.1	21.5
50	1.5306	5.2	10.3	15.4	20.7
51	1.5006	5.0	9.9	14.8	19.8
52	1.4718	4.8	9.6	14.3	19.1
53	1.4440	4.6	9.2	13.7	18.4
54	1.4173	4.5	8.9	13.2	17.7
55	1.3915	4.3	8.6	12.7	17.1
56	1.3666	4.2	8.2	12.3	16.5
57	1.3427	4.0	8.0	11.9	15.9
58	1.3195	3.9	7.7	11.5	15.3
59	1.2972	3.8	7.4	11.1	14.8
60	1.2755	3.6	7.2	10.7	14.3
61	1.2546	3.5	7.0	10.4	13.9
62	1.2344	3.4	6.7	10.0	13.4
63	1.2148	3.3	6.5	9.7	13.0
64	1.1958	3.2	6.3	9.4	12.6
65	1.1774	3.1	6.1	9.1	12.2
66	1.1596	3.0	5.9	8.8	11.8
67	1.1423	2.9	5.8	8.6	11.5
68	1.1255	2.8	5.6	8.3	11.2
69	1.1092	2.7	5.4	8.1	10.8
70	1.0933	2.7	5.3	7.9	10.5
71	1.0779	2.6	5.1	7.6	10.2
72	1.0629	2.5	5.0	7.4	10.0
73	1.0484	2.5	4.9	7.2	9.7
74	1.0342	2.4	4.7	7.0	9.4
75	1.0204	2.3	4.6	6.9	9.2
76	1.0070	2.3	4.5	6.7	8.9
77	0.9939	2.2	4.4	6.5	8.7
78	0.9812	2.1	4.3	6.3	8.5
79	0.9688	2.1	4.1	6.2	8.3
80	0.9567	2.0	4.0	6.0	8.1
81	0.9448	2.0	3.9	5.9	7.9
82	0.9333	1.9	3.8	5.7	7.7
83	0.9221	1.9	3.8	5.6	7.5
84	0.9111	1.9	3.7	5.5	7.3
85	0.9004	1.8	3.6	5.3	7.1

4. Mechanical Profiles

The gratings were designed to be large enough to accept the input beams for various grating angles while still allowing some clear aperture to the end of the ruling. The substrates were sized to give some extra spacing around the ruling. In both cases, the extra spacings are large enough to allow for the kind of misalignment we have required in other elements in the instrument. They are small enough to give adequate spacing between the gratings and nearby optical assemblies.

The maximum beam footprint at the echelle is shown in Figure 2. The small dots show where rays from the entrance pupil strike the echelle. The point of view is looking into the echelle along the grating normal. The extra ruling of 3.1 mm on either side in the long dimension allows about 1.2 mm of extra ruling as seen by the beam. We originally wanted 2 mm of apparent extra ruling, but Spectronic, Inc., do not make a grating which is larger than the one shown in Figure 2. The final dimensions are 132X312 mm of ruled area, and 142X320X50.8 mm of substrate. Note: grating dimensions are usually expressed as groove length X ruled width.

One extreme case for the cross-disperser is shown in Figure 3. This case corresponds to the pure imaging mode ($m_{cd} = 0$) where the input and output beams are 25° degrees apart and are bisected by the grating normal. The complex of footprints is shifted to the left in the figure from the center of the grating. This shift is due to the fact that, in this mode, the echelle is replaced by a mirror which is 3 inches closer to the collimator and cross-disperser. This longitudinal shift will produce a lateral shift of the beam as seen by downstream elements. The final dimensions are 206X186 mm of ruled area, and 220X200X38.1 mm of substrate.

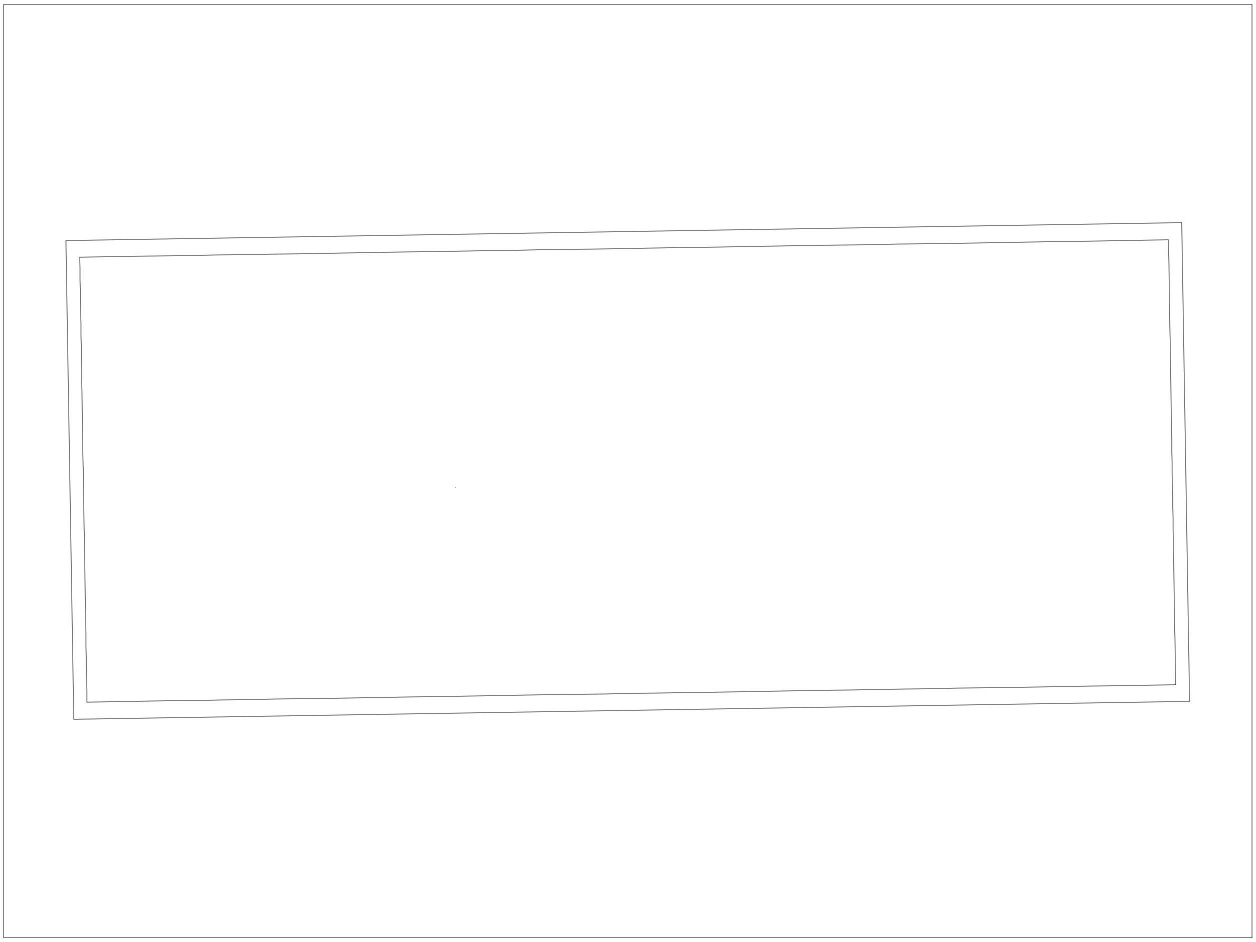

Figure 2. Maximum footprint at echelle. This case is for $\alpha = 66.8°$. Notice the small dots which correspond to points on the tangential and sagittal axes at the Keck primary. This grating size allows 3.1 mm (5.5 mm) extra ruling on either side of the long dimension (short dimension). In addition, the substrate is oversized by 4 mm (5 mm) on either side of the long dimension (short dimension). The final dimensions are 132X312 mm of ruled area, and 142X320X50.8 mm of substrate. Note: grating dimensions are usually expressed as groove length X ruled width.

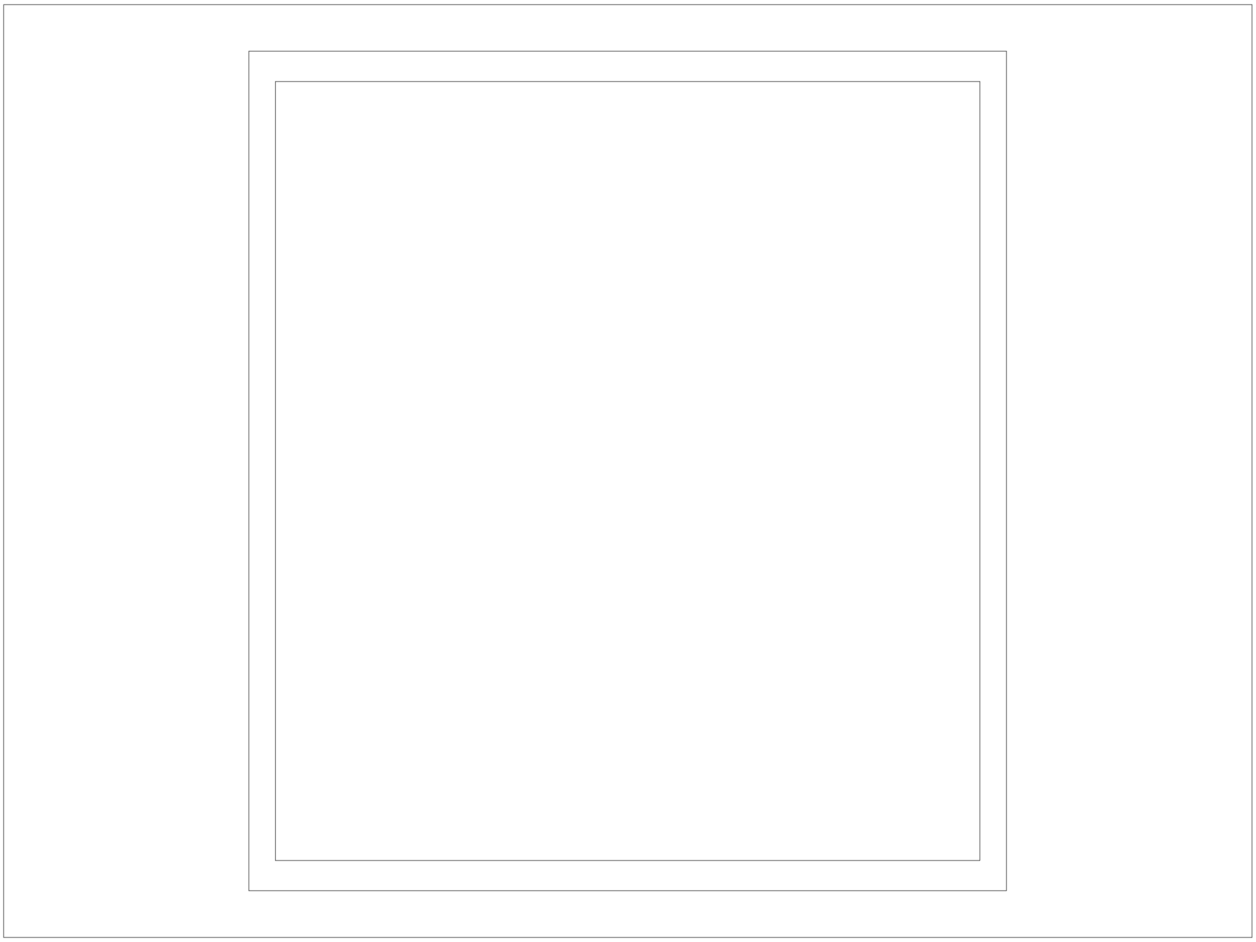

Figure 3. Maximum footprints at cross-disperser. This case is for $\alpha_{cd} = 25°$, the case for the pure imaging mode where the cross-disperser is used in zero order. The small dots correspond to 5 field points, center and corners, and various pupil positions. The tightest area is at the left edge where there is 2.1 mm of extra ruling available. This translates into 1.9 mm of apparent extra ruling, very close to the desired value of 2.0 mm. There is at least this much extra ruling on the right side of the grating, and the ruling is 5 mm oversized on each side of the long dimension. We allow 7 mm of extra substrate all the way around. The final dimensions are 206X186 mm of ruled area, and 220X200X38.1 mm of substrate.

5. Grating Surface and Substrate Tolerances

The optical requirements for the gratings are that the surfaces do not induce significant wavefront error (WFE), that the beams are properly positioned with respect to the ruling, and that the beams are properly steered into downstream elements.

The WFE constraint requires a surface irregularity of $< \lambda_{HeNe}/5$ RMS (see the WFE design note, NODN1100). Spectronic Instruments, Inc., inform us that this can be maintained if the substrate surface is flat to within a few microns. Evidently, the glue between the ruling and substrate will fill in any irregularity on the substrate surface so that the final irregularity is controlled solely by the flatness of the master itself.

Tolerances on the position of the ruling are given in the optomechanical design note, NODN0900. Even after placing the ruling on the substrate within the required tolerances, the grating must still be positioned within the mechanism, and the mechanism within the instrument, to preserve proper alignment with respect to the beam. The total error from these procedures should be less than 0.5 mm of translation along the long axis of the grating, 1.0 mm along the short axis, and 2.0 mm in longitudinal shift; all are with respect to the nominal position as defined by the beam. It is possible to distribute this error to any of the sources of misalignment given above. It is possible to violate these requirements in placing the ruling on the substrate and then compensate for this by adjusting the mount or mechanism. Of course, this method cannot be taken to an extreme - the ruling must be on the substrate! Spectronic, Inc., claim that they can place the ruling on the substrate to within these errors anyway. This would preserve the clear space between the ruling and the edge of the substrate, although we do not anticipate using this clear space for mounting purposes.

The beam steering requirements constrain the ruled surfaces to be aligned such that lateral offset of the beam on any element does not exceed 1 mm. The nature of the grating mounts gives motion in one axis. So, we have altitude adjustment in the echelle mechanism and azimuth adjustment in the cross-disperser mechanism. In addition, we will adjust the positions of the mechanisms in the other degrees of freedom so that they are “aligned.” The table in NODN0900 shows that we must adjust the echelle to within 0.3 mrad azimuth and the cross-disperser to within 1.2 mrad in altitude. These requirements do not constrain the manufacturing of the substrates or placement of the rulings on them. Instead, they will have to be achieved by adjusting the mounts and mechanisms which are connected to the gratings. This alignment procedure will compensate for any misfabrication (non-parallelism), and would have to be done regardless of manufacturing error in the gratings.

If sufficient adjustments are provided in the grating mounts, then these position requirements, constrained by beam offset and beam steering, do not have an impact on the grating design or substrate fabrication. We will assume that this is the case and place liberal tolerances on the grating sizes and parallelism.

Appendix A: Gratings RFQ

April 15, 1996

John Hoose
Manager, Gratings Marketing and Sales
Richardson Grating Laboratory
Spectronic Instruments Inc.
820 Linden Avenue
Rochester NY 14625

Dear John,

Please find enclosed our formal request for quote (RFQ) to fabricate two gratings for the NIRSPEC cryogenic spectrometer. The echelle grating will be replicated from an existing master, while the cross-disperser grating will be replicated from a new master to be ruled on the Chicago engine. In both cases, we will provide the substrates of thermally cycled aluminum.

As per our telecon of last Wednesday (April 10), we expect that the new quotes would be the same as those given last year. You gave a cost of $57,000 for the cross-disperser (fax from John Hoose to Don Figer, May 10, 1995, Subject Code #95-1736), and $19,700 for the echelle (fax from Sue Willard and Jerry Quartz to Don Figer, May 24, 1995).

Please fax, and send, a formal quote to produce these items. We will try to turn these around through accounting and then start a contract as soon as possible.

Sincerely,

Don Figer

enclosed: formal RFQ

NIRSPEC

UCLA Astrophysics Program **U.C. Berkeley** **W.M. Keck Observatory**

Don Figer **April 15, 1996**

Request for Formal Quote

Echelle and Cross-disperser Gratings

1.0 Introduction

This document is a solicitation for formal quote to produce two diffraction gratings for use in the NIRSPEC instrument, a cryogenic (77 K), high resolution, near-infrared spectrometer being built for the Keck II telescope. We have included a specification table and mechanical drawings. We require delivery no later than 9 months after contract award.

2.0 Specifications

Ordering specifications are given in the table below. In addition, we note that the substrates will be made of thermally destressed aluminum (6061-T6) to be supplied by UCLA.

Specifications for NIRSPEC Gratings

Item	Echelle	Cross-Disperser
Catalog #	35-13-*-412	35-53-*-856
Master #	MR149	custom
Blaze angle	63°.0±0°.5	10°.0±0°.5
Efficiency (order)[1]	> 70% (39)	> 75% (1)
Ruled area[2]	132 X 312 mm	206 X 186 mm
Bare substrate area	142 X 320 mm	222[4] X 200 mm
Wavefront error[3]($\lambda_{HeNe,PV}$)	< 2/5	< 2/5

[1] Efficiency is with respect to an aluminum mirror and is measured near-Littrow, at blaze peak, and in the specified order.

[2] The ruled area is expressed as (ruled length X ruled width).

[3] This should be maintained over the whole ruled area for the echelle and over any 150 mm diameter subaperture on the cross-disperser.

[4] We later found out that Spectronic, Inc. would rather have this dimension be 220 mm. We found no problem with this, and subsequently changed the value.

3.0 Coatings

We require a gold coating for maximum reflectivity from 1 to 5 μm, comparable to either a FSS-99 or FSG-98 coating from Denton Vacuum (Morrestown, NJ). The best choice for performance, adhesion, and durability should be jointly determined during the initial portion of the contract. We require that the coating surface be maintained after many thermal cycles from room temperature to operating temperature, 77 K.

4.0 Mechanical Requirements

We require that any machine work done on the substrates or tooling which comes into contact with the substrates not induce stress or change the mechanical profile of the substrates. We will work with the vendor in determining the best locations for mounting or fixture holes. The substrates will be thermally relaxed before being sent to the vendor. Any stresses induced by the vendor should result in no deviation in performance with respect to the specifications in the table. The gratings should maintain these specifications after many cycles thermal cycles from room temperature to operating temperature, 77 K.

5.0 Acceptance Testing and Documentation

Adequate documentation should be provided to verify that the gratings perform as indicated in the specification table.

Appendix B: Substrates RFQ

NIRSPEC

UCLA Astrophysics Program U.C. Berkeley W.M. Keck Observatory

Don Figer figer@astro.ucla.edu
UCLA
Division of Astronomy & Astrophysics
Department of Physics & Astronomy
8371 Math Sciences
Box 951562 Phone: **310-825-1666**
Los Angeles, CA 90095-1562 Fax: **310-206-7254**

IMPORTANT: SEND ALL MAIL TO THE ABOVE ADDRESS!

May 13, 1996

To: **Contact**
ABC, Inc.
Phone: AC-NNN-NNNN Fax: AC-NNN-NNNN

Message:

Request for Formal Quote

This is a formal request for quote to fabricate two each of two grating substrates to be used in the NIRSPEC instrument, a cryogenic, high-resolution, near-infrared spectrometer for the Keck II telescope. The substrates must be made of thermally destressed aluminum (6061-T6). We require a flatness of 3 μm PV, and an RMS surface roughness less than 5000 Å, but more than 1000 Å. The roughness should be random, i.e. no periodic markings from fly cutting. The final surface should have no plating or coating. The substrates have the following dimensions: 320X142X50.8 mm (“E”) and 220X200X38.1 mm (“CD”). The qualified areas are: a 320X142 mm ellipse on “E” and any 150 mm diameter circle on “CD”. The relative parallelism between the front and back surface need be no better than 1 arcmin. The tolerance on all dimensions is ±0.025 mm.