
NIRSPEC

UCLA Astrophysics Program

U.C. Berkeley

W.M. Keck Observatory

Don Figer

October 25, 1998

NIRSPEC Optics Design Note 8.00 Back-end Design

I.	Introduction	2
II.	NIRSPEC System Design Requirements	3
III.	Optical System Design Requirements for back-end	5
IV.	Collimator design	8
V.	Gratings Design and instrument modes	8
VI.	TMA Design	9
VII.	Complete back-end Design	9
	Appendix A: System/Prescription Data: Surface Prescription	14
	Appendix B: System/Prescription Data: Surface Detail	17
	Appendix C: System/Prescription Data: Global Vertex Data	21

I. Introduction

This document describes the system design parameters and optical designs for the NIRSPEC back-end optics, including all elements from the slit to the detector. The primary purpose of the document is to describe the system-level optical performance of the back-end optics, as opposed to being a complete detailed description of the optical sub-components in the back-end. The latter information can be found in other documents, as described in the following individual sections.

Preliminary back-end lens designs were investigated throughout the period from the proposal phase to past the Preliminary Design Review (PDR), and can be found in the associated documents. The final design will be discussed here. Table 1 gives a cross-reference list of other documentation concerning all aspects of the back-end design.

Table 1: Document Cross-Reference

Topic	Document
system design	NIRSPEC PDR (9/1/95) NIRSPEC CDR (2/8/96) NODN0100 NODN0700
slits	NODN2200
collimator	NODN1300
gratings	NODN1700
TMA	“Specifications for TMA” (Optics 1, 9/19/95) Phase A Design Study (SSG, 1/26/96) “Optical Design & Analysis” (SSG, 8/14/96) TMA CDR (SSG, 8/14/96) Final Report (SSG, 9/24/97) TMA ATP (SSG, 9/27/97) “Cryogenic Performance of the NIRSPEC TMA” (SPIE 3354, 1068)
TMA focal length	NODN2100
System ATP	NODN2600
baffle design	NODN1500 NODN2400 BRO report #2820
transmission	NODN2700
image performance	NODNXXXX “WFE budget and optomechanical tolerancing for NIRSPEC” (SPIE 3354, 1005)

II. NIRSPEC System Design Requirements

An optical block diagram is shown in Figure 1. The instrument can be divided into three sections: 1) external optics, i.e., the calibration unit and guider, 2) the front-end, and 3) the back-end. The window is the natural dividing point for the external optics and front-end, while the slit is the dividing point between the front-end and the back-end.

The system optical requirements are given in Table 2. The properties of the beam are described in Table 3.

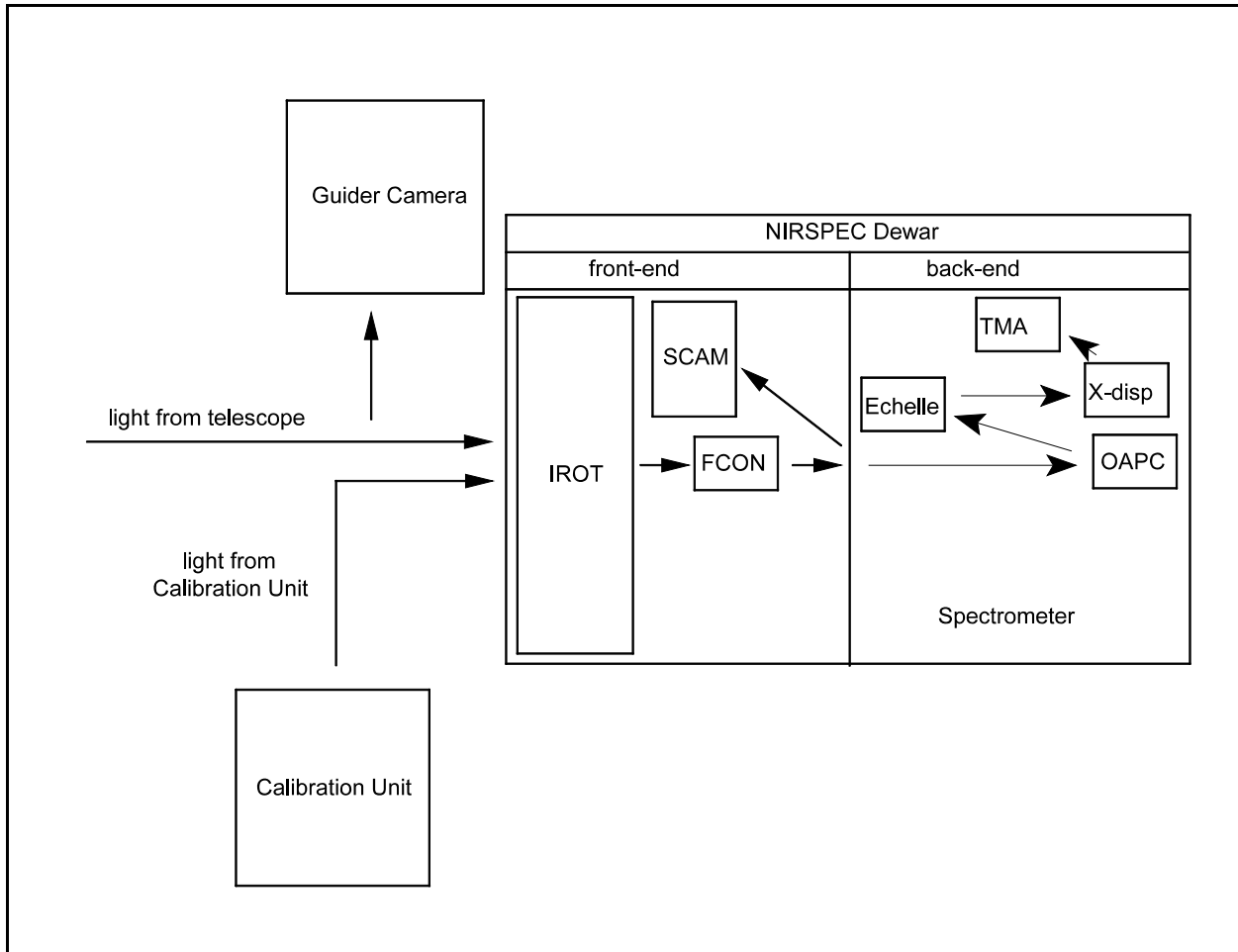


Figure 1. Block diagram of NIRSPEC optics.

Table 2: Optical System Requirements

Parameter	Spec.
EPE (enpixelled energy)	> 70%
collimated beam	120 mm
high-res mode	R - 25,000 for 0.4 arcsec slit
low-res mode	R - 2,500 for 0.4 arcsec slit
focal length of back-end camera	- 420 mm
spectral coverage	1-5 μm
transmission	> 98%/reflective (non-dispersive) optic
surface roughness	< 40 D (RMS)/reflective (non-dispersive) optic

Table 3: Optical properties of beam

Location	Output Angle Between Extreme Chief Rays	Output Angle Between Marginal Rays for Axial Field Point	Output Beam	
primary	$65^\circ = 0^\circ 0181$	$32^\circ 5$	converging	f/1.75
secondary	$0^\circ 1375$	$3^\circ 8$	converging	f/15
focal plane	$0^\circ 1375$	$3^\circ 8$	diverging	f/15
window	$0^\circ 1375$	$3^\circ 8$	diverging	f/15
collimator	$16^\circ 94$	0°	collimated	-
Lyot stop	$6^\circ 92$	0°	collimated	-
f/converter	0°	$5^\circ 72$	converging	f/10
slit	0°	$5^\circ 72$	diverging	f/10
collimator	0°	0°	collimated	-
echelle	$3^\circ 5$ (disp. plane)	0°	collimated	-
x-disperser	$3^\circ 5$ (disp. plane)	0°	collimated	-
TMA	$2^\circ 3$	$16^\circ 3$	converging	f/3.5
detector	$2^\circ 3$	$16^\circ 3$	diverging	f/3.5

III. Optical System Design Requirements for back-end

The impact of the system design requirements on the back-end are:

- S 120 mm collimated beam
- S echelle and cross-disperser gratings (see NODN1700)
- S - f/3 camera design with a wide field of view ($\sim 3.5^\circ$)
- S baffle design to block unwanted orders (see NODN1500)

The back-end optical design has been divided into 3 sections or modules, the collimator, the gratings section, and the camera. These sections can be clearly identified in Figures 2 and 3.

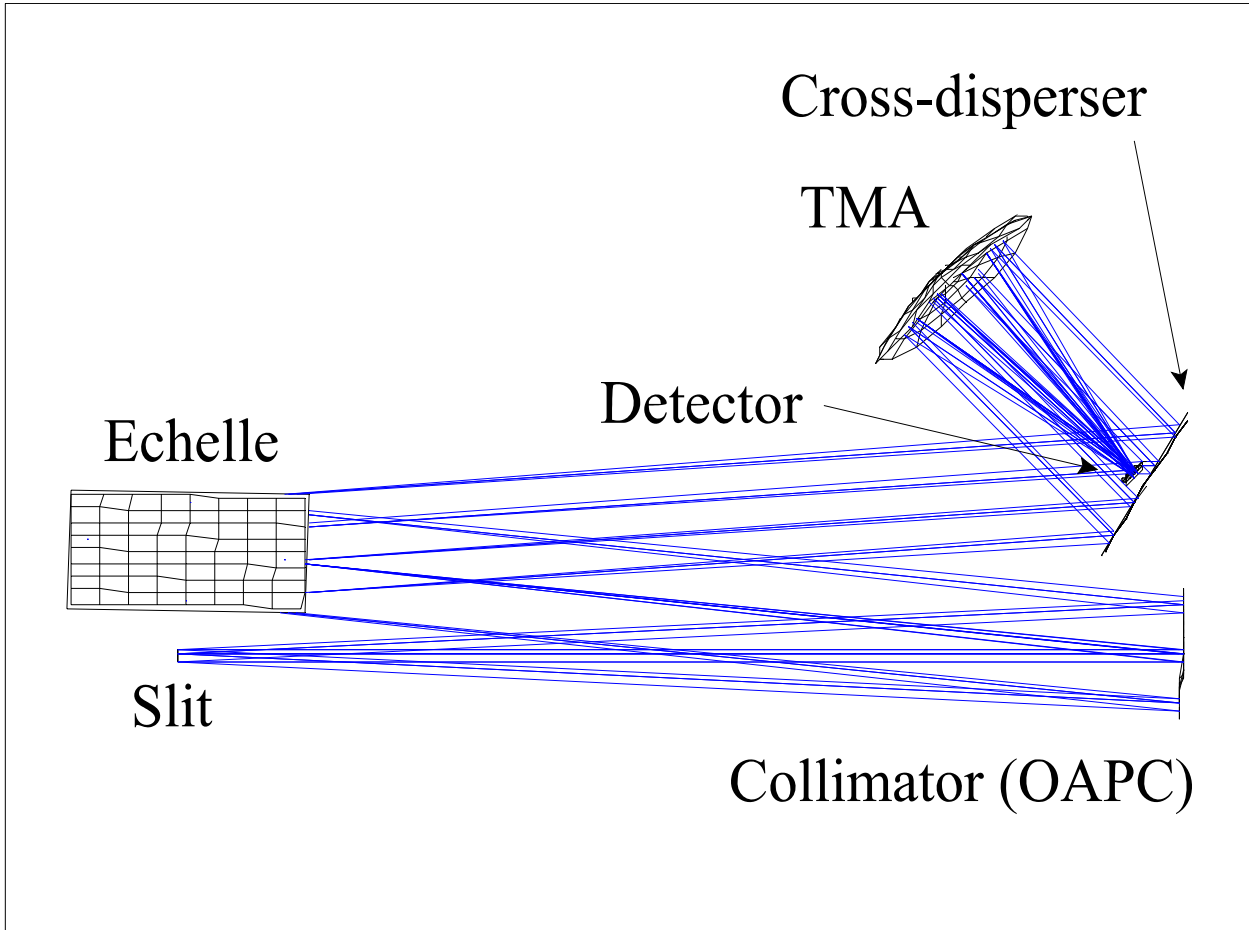


Figure 2. Top-view of NIRSPEC back-end design.

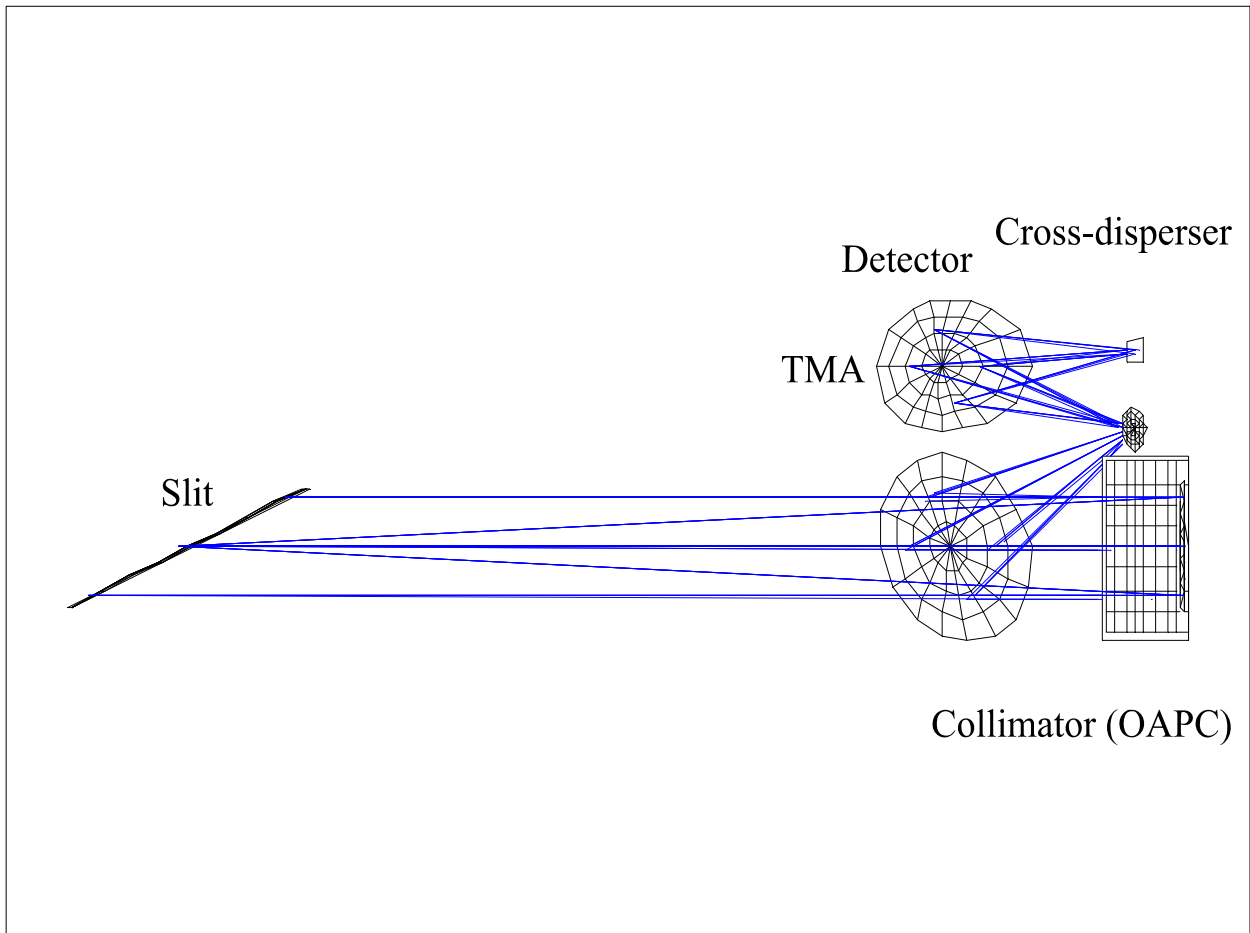


Figure 3. Side-view of NIRSPEC back-end design.

IV. Collimator design

The collimator design is described in NODN1300. A summary of the optical properties is given in Table 4.

Table 4: Optical Properties of Collimator

Parameter	Value
Focal Length	1200 mm
Clear Aperture	139 mm
Off-axis angle	6°

V. Gratings Design and instrument modes

The gratings designs are discussed in the gratings bid package (see NODN1700). Briefly, the echelle grating is used in the “quasi-Littrow” mode, i.e., the angle between the input and output beams in the plane of dispersion is zero for the gut ray, and the out-of-plane angle is nonzero. The cross-disperser is used with a fixed opening angle of 50° between the input and output angles in the plane of dispersion.

Table 5 gives a summary of design characteristics of the gratings.

Table 5: Grating properties

Parameter	Echelle	Cross-Disperser
Master #	MR149-1-5-1	MR182-2-1-1
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	220 X 200 mm

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

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

VI. TMA Design

Extensive documentation on the TMA design already exists in the documents listed in Table 1. In brief, the TMA utilizes an elliptical primary, hyperbolic secondary, and elliptical tertiary, (all simple conics) in order to provide an unobscured, fast, achromatic camera. A TMA can be corrected for spherical, coma, and astigmatism. The TMA keystone distortion almost perfectly cancels the anamorphic magnification due to the echelle grating, giving constant sampling of the slit across each echelle order.

Optics 1, Inc. and SSG, Inc. have designed the TMA with the following properties: EFL = 420 mm, Aperture Diameter = 120 mm, F/# = 3.5, FOV = 3.5° by 3.5°. Manufacturing is a critical issue. The substrates were machined from T6061-T6 Al. They were nickel-plated, post-polished (RMS roughness = 20D), and silver coated for increased reflectivity. The camera is housed in an athermalized structure.

VII. Complete back-end Design

A full optical prescription is given in the appendix. Data in the appendices can be reproduced by using the “report” feature in Zemax, and selecting the appropriate options.

Appendix A gives the basic optical prescription which sets up the design in Zemax. The telescope is included (surfaces zero through 3). The back-end starts at the slit, surface 42. Notice the many coordinate breaks which serve to apply tilts and decenters.

Appendix B gives surface detail, including the amount of tilt and decenter and aperture mask sizes.

Appendix C gives the global vertex positions of the various elements. This table provides for an excellent check to see if the prescription is the one we built. Any change in the Zemax file will produce some change in these numbers.

A summary of the performance is given in the form of spot diagrams in the following. The figures give spot diagrams for various locations across the array and along the slit. In order to “probe” the performance across the detector, I changed the wavelengths. For instance, when looking from the TMA toward the face of the detector, the top edge of the field corresponds to a wavelength of 1.13375 μm , the center to 1.14230 μm , and the bottom to 1.15110 μm , for the central order. To probe the detector side-to-side, I had to change the wavelengths and the orders. Lower orders (longer wavelengths) are to the right of the detector. The field angles are in degrees and correspond to angles on the sky, i.e., 0.0042° is equivalent to 15 λ . Notice that this implies a slit length which is longer than the longest high resolution slit (24 λ), so the spots will be a bit pessimistic.

The performance produces spots which are mostly within the 1-pixel wide boxes. This is consistent with the predicted enpixelled energies given in “WFE budget and optomechanical tolerancing for NIRSPEC” (SPIE 3354, 1005).

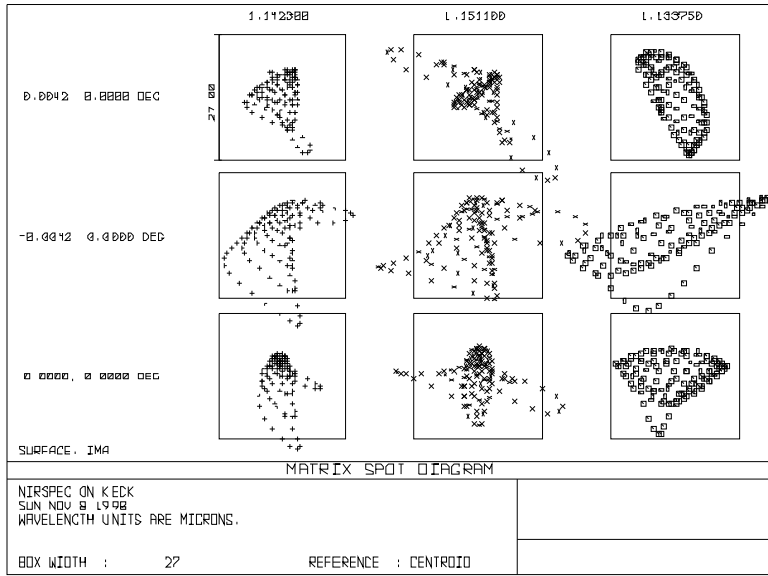


Figure 4. Spot diagrams for central order along the slit. Longer wavelengths are located at the bottom of the array. The field angles are in degrees and correspond to angles on the sky, i.e., 0.0042° is equivalent to $15''$. Notice that this implies a slit length which is longer than the longest high resolution slit (240). Box size corresponds to one pixel.

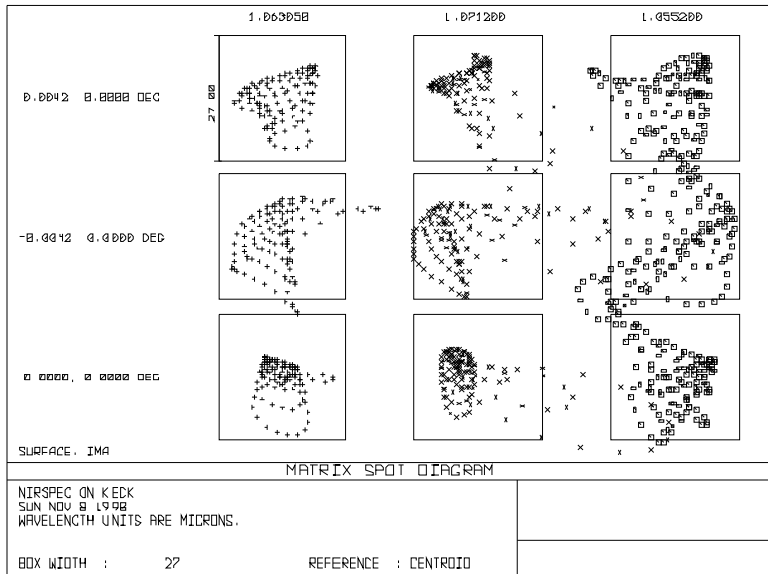


Figure 5. Spot diagrams for leftmost order.

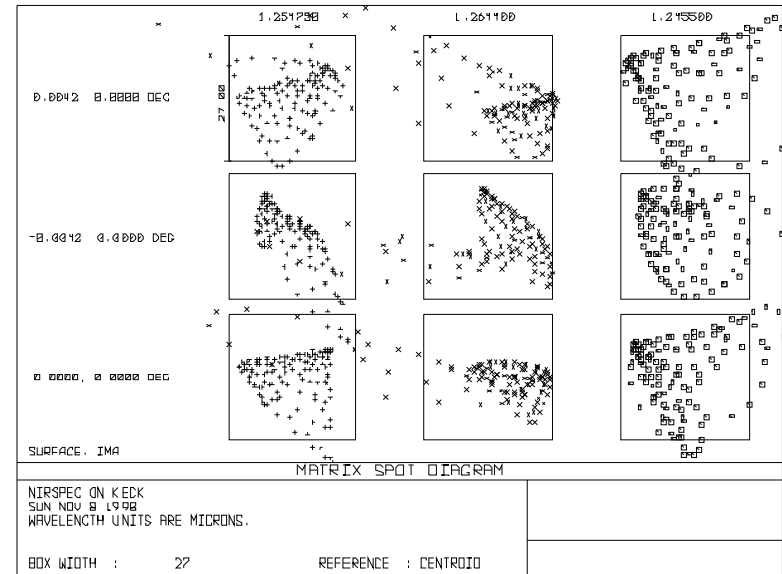


Figure 6. Spot diagrams for rightmost order.

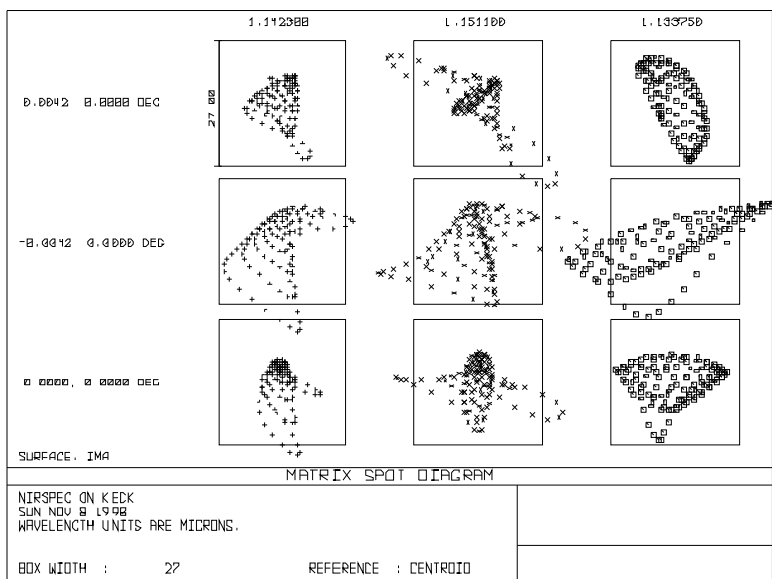


Figure 7. IROT = 0°. Positive angles are toward SCAM.

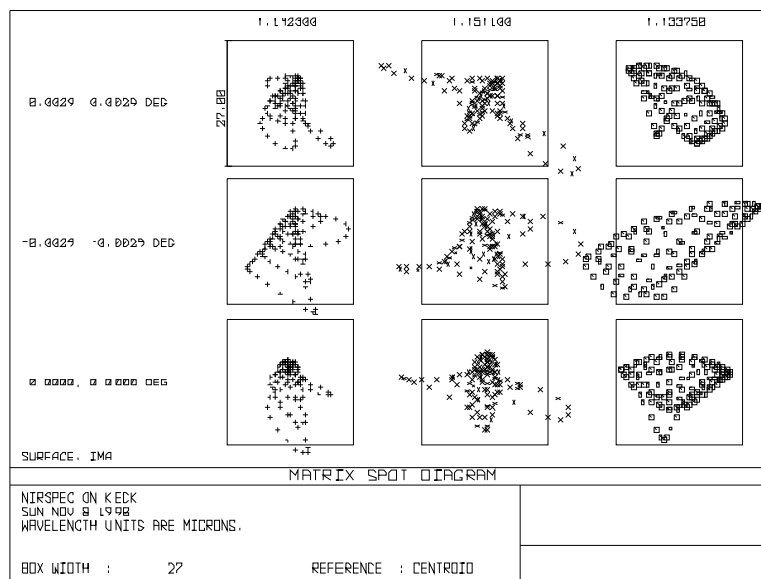


Figure 8. IROT = 22.5°.

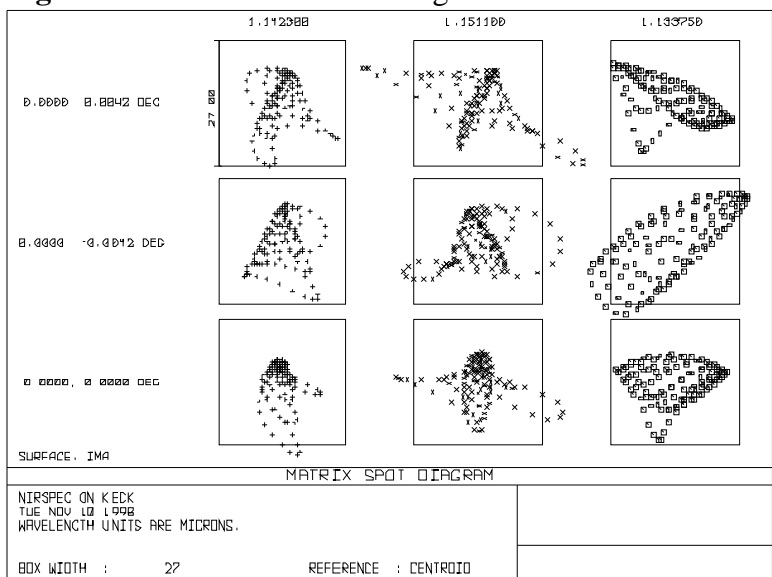


Figure 9. IROT = 45°.

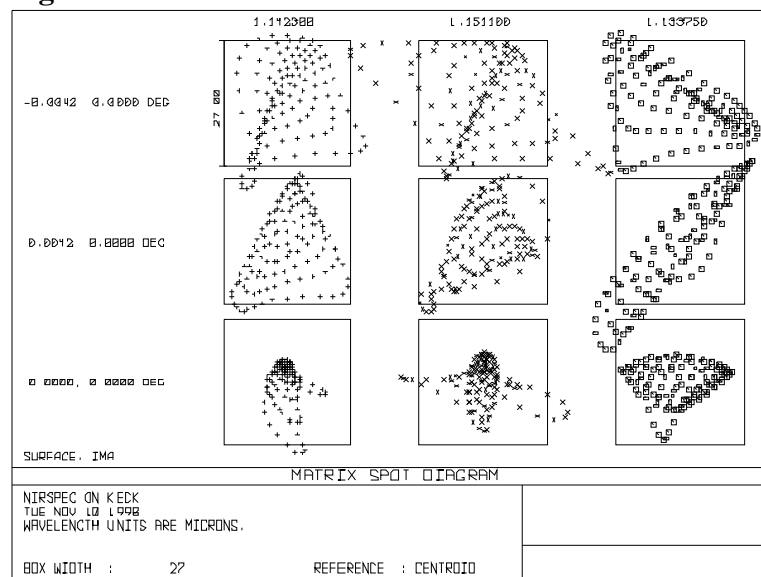


Figure 10. IROT = 90°.

The following give spot diagrams for various negative image rotator positions and the central order. Notice that system performance is not symmetric about the image rotator zero angle. This is because the 3 parabolas in the design are not in the same plane.

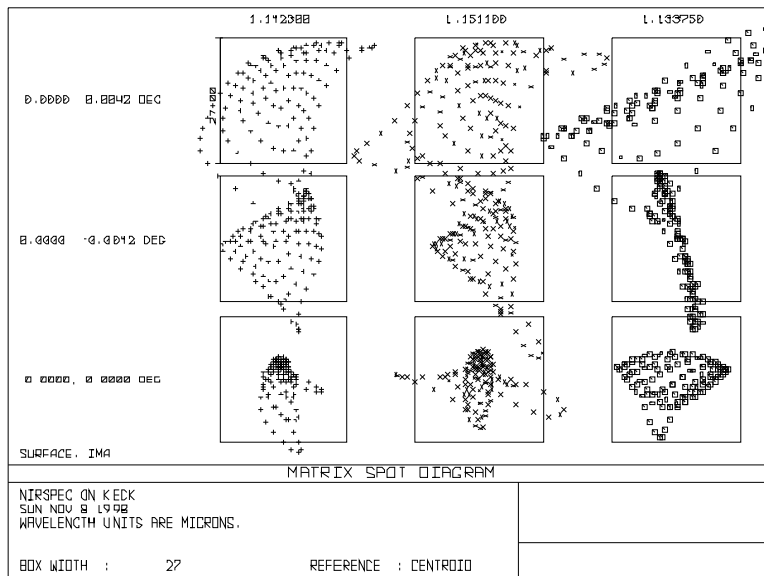


Figure 11. IROT = -45°.

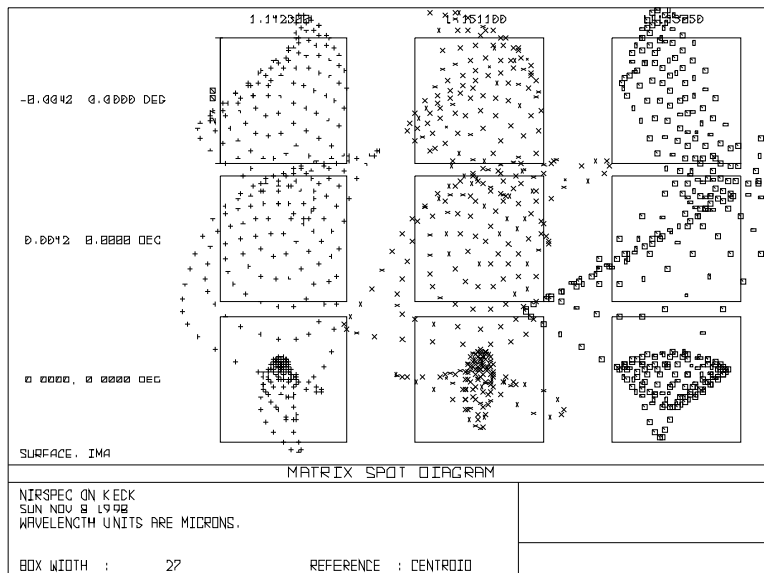


Figure 12. IROT = -90°.

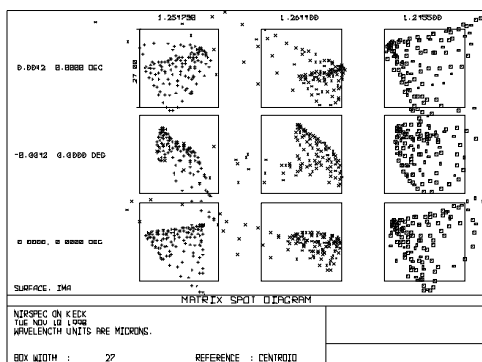


Figure 13. IROT = 0°.

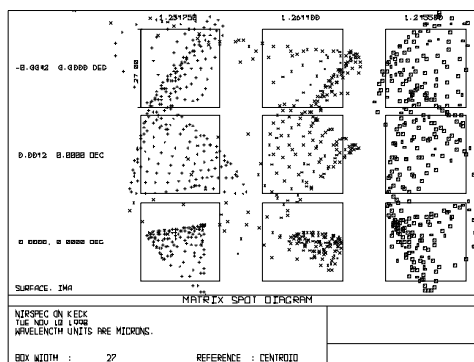


Figure 14. IROT = 90°.

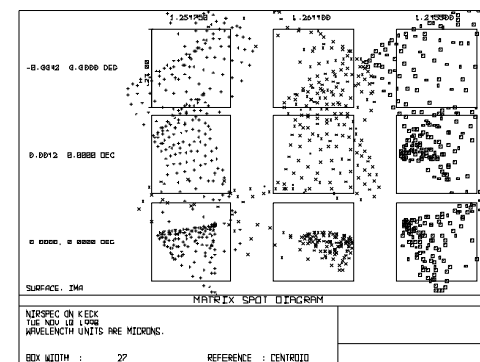


Figure 15. IROT = -90°.

The above and below figures give spot diagrams for the extreme orders for an image rotator angle of 0°, 90°, and -90° degrees.

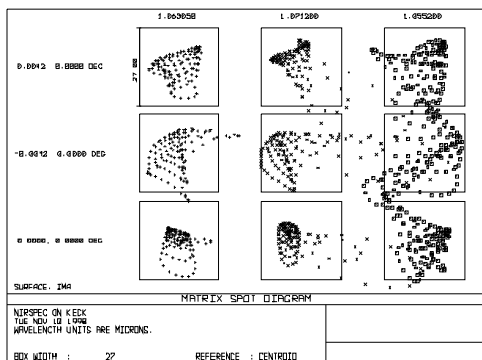


Figure 16. IROT = 0°.

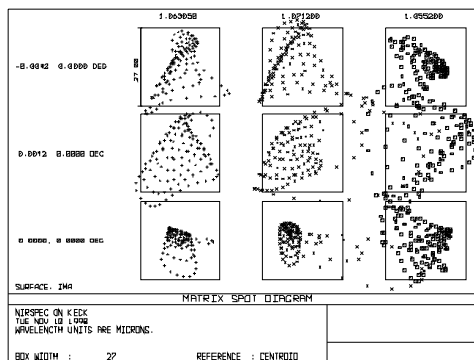


Figure 17. IROT = 90°.

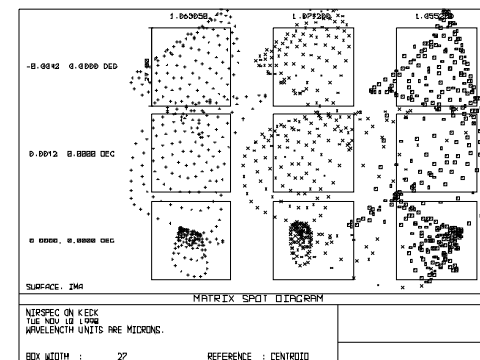


Figure 18. IROT = -90°.

Appendix A: System/Prescription Data: Surface Prescription

File : D:\lenses\nirspec\endtoend\Tmakck24.zmx
 Title: NIRSPEC ON KECK
 Date : SUN NOV 8 1998

LENS NOTES:

Notes...

SURFACE DATA SUMMARY:

Surf	Type	Comment	Radius	Thickness	Glass	Diameter	Conic
OBJ	STANDARD		Infinity	Infinity		0	0
1	STANDARD		Infinity	16.65		0.4914	0
STO	STANDARD		-34.974	-15.39499	MIRROR	10	-1.003683
3	STANDARD		-4.737916	17.89498	MIRROR	1.309857	-1.644326
4	STANDARD		Infinity	0.03063336		0.0471791	0
5	STANDARD		Infinity	0.0075	CAFL	0.052	0
6	STANDARD		Infinity	0.06		0.052	0
7	COORDBRK		-	0	-	-	-
8	COORDBRK		-	0	-	-	-
9	COORDBRK		-	0	-	-	-
10	STANDARD		Infinity	0	MIRROR	0.07024257	0
11	COORDBRK		-	-0.304085	-	-	-
12	COORDBRK		-	0	-	-	-
13	COORDBRK		-	0	-	-	-
14	COORDBRK		-	0	-	-	-
15	COORDBRK		-	-0.00408495	-	-	-
16	COORDBRK		-	0	-	-	-
17	STANDARD		0.7918301	0	MIRROR	0.2200278	-1
18	COORDBRK		-	0.00408495	-	-	-
19	COORDBRK		-	0.304085	-	-	-
20	COORDBRK		-	0	-	-	-
21	STANDARD		Infinity	0	MIRROR	0.0513835	0
22	COORDBRK		-	-0.1036465	-	-	-
23	COORDBRK		-	0	-	-	-
24	STANDARD		Infinity	-0.002	CAF2_77X	0.02744924	0
25	STANDARD		Infinity	-0.048		0.02728572	0
26	COORDBRK		-	0	-	-	-
27	COORDBRK		-	0	-	-	-
28	STANDARD		Infinity	0	MIRROR	0.04318231	0
29	COORDBRK		-	0.2180015	-	-	-
30	COORDBRK		-	0	-	-	-
31	COORDBRK		-	0.00273089	-	-	-
32	STANDARD		-0.5293582	0	MIRROR	0.1542775	-1
33	COORDBRK		-	-0.00273089	-	-	-

34	COORDBRK	-	0	-	-	-
35	COORDBRK	-	0	-	-	-
36	COORDBRK	-	-0.2180015	-	-	-
37	COORDBRK	-	0	-	-	-
38	STANDARD	Infinity	0	MIRROR	0.04874423	0
39	COORDBRK	-	0.04943166	-	-	-
40	COORDBRK	-	0	-	-	-
41	COORDBRK	-	0	-	-	-
42	STANDARD	Infinity	1.203296	-	0.03192669	0
43	COORDBRK	-	0	-	-	-
44	COORDBRK	-	0	-	-	-
45	COORDBRK	-	0.003295879	-	-	-
46	COORDBRK	-	0	-	-	-
47	STANDARD	-2.4	0	MIRROR	0.3868066	-1
48	COORDBRK	-	0	-	-	-
49	COORDBRK	-	-1.203296	-	-	-
50	COORDBRK	-	0	-	-	-
51	COORDBRK	-	0	-	-	-
52	COORDBRK	-	0	-	-	-
53	COORDBRK	-	0	-	-	-
54	DGRATING	Infinity	0	MIRROR	0.2663462	0
55	STANDARD	Infinity	0	-	0.2663462	0
56	COORDBRK	-	0	-	-	-
57	COORDBRK	-	0	-	-	-
58	COORDBRK	-	0	-	-	-
59	COORDBRK	-	0	-	-	-
60	COORDBRK	-	1.15	-	-	-
61	COORDBRK	-	0	-	-	-
62	COORDBRK	-	0	-	-	-
63	DGRATING	Infinity	0	MIRROR	0.242659	0
64	STANDARD	Infinity	0	-	0.242659	0
65	COORDBRK	-	0	-	-	-
66	COORDBRK	-	0	-	-	-
67	COORDBRK	-	-0.35	-	-	-
68	COORDBRK	-	0	-	-	-
69	COORDBRK	-	0	-	-	-
70	STANDARD	0.6785632	0	MIRROR	0.6572571	-0.6715615
71	COORDBRK	-	0.3303097	-	-	-
72	COORDBRK	-	0	-	-	-
73	COORDBRK	-	0	-	-	-
74	STANDARD	0.2312846	0	MIRROR	0.1553534	-4.945295
75	COORDBRK	-	0	-	-	-
76	COORDBRK	-	0	-	-	-
77	COORDBRK	-	-0.332994	-	-	-
78	COORDBRK	-	0	-	-	-
79	COORDBRK	-	0	-	-	-
80	STANDARD	0.3303025	0	MIRROR	0.1505898	-0.07739628
81	COORDBRK	-	0	-	-	-
82	COORDBRK	-	0	-	-	-
83	COORDBRK	-	0.2531544	-	-	-
84	COORDBRK	-	0	-	-	-

85	COORDBRK	-	0	-	-	-
86	COORDBRK	-	0	-	-	-
87	COORDBRK	-	0.08141773	-	-	-
88	COORDBRK	-	0	-	-	-
89	COORDBRK	-	0	-	-	-
90	COORDBRK	-	0	-	-	-
91	COORDBRK	-	0	-	-	-
92	COORDBRK	-	0	-	-	-
IMA	STANDARD	Infinity			0.04022466	0

Appendix B: System/Prescription Data: Surface Detail

```

F i l e : Tilt About Y : 0 Order : Decenter then tilt
D:\lenses\nirspec\endtoend\Tmakck24.z Tilt About Z : 0 Surface 16 : COORDBRK
mx Order : Decenter then tilt Decenter X : 0
Title: NIRSPEC ON KECK Surface 9 : COORDBRK Decenter Y : 0
Date : SUN NOV 8 1998 Decenter X : 0 Tilt About X : 0
Decenter Y : 0 Tilt About Y : 0
LENS NOTES: Tilt About X : -47.9 Tilt About Z : 0
Notes... Tilt About Y : 0 Order : Decenter then tilt
Tilt About Z : 0 Surface 17 : STANDARD
Order : Decenter then tilt Aperture : Circular Aperture
Surface 10 : STANDARD Minimum Radius : 0
Aperture : Rectangular Aperture Maximum Radius : 0.0396
X Half Width : 0.02905 Y- Decenter : -0.080431201
Y Half Width : 0.0448 Surface 18 : COORDBRK
Surface 11 : COORDBRK Decenter X : 0
Decenter X : 0 Decenter Y : -0.080431168
Decenter Y : 0 Tilt About X : 0
Tilt About X : -47.9 Tilt About Y : 0
Tilt About Y : 0 Tilt About Z : 0
Tilt About Z : 0 Order : Decenter then tilt
Order : Decenter then tilt Surface 19 : COORDBRK
Surface 12 : COORDBRK Decenter X : 0
Decenter X : 0 Decenter Y : 0
Decenter Y : 0 Tilt About X : 0
Tilt About X : 0 Tilt About Y : 0
Tilt About Y : 0 Tilt About Z : 0
Tilt About Z : 0 Order : Decenter then tilt
Order : Decenter then tilt Surface 20 : COORDBRK
Surface 13 : COORDBRK Decenter X : 0
Decenter X : 0 Decenter Y : 0
Decenter Y : 0 Tilt About X : -47.9
Tilt About X : 11.6 Tilt About Y : 0
Tilt About Y : 0 Tilt About Z : 0
Tilt About Z : 0 Order : Decenter then tilt
Order : Decenter then tilt Surface 21 : STANDARD
Surface 14 : COORDBRK Decenter X : 0
Decenter X : 0.080431168 Aperture : Rectangular Aperture
Decenter Y : 0 X Half Width : 0.02015
Tilt About X : 0 Y Half Width : 0.034
Tilt About Y : 0 Surface 22 : COORDBRK
Tilt About Z : 0 Decenter X : 0
Tilt About Z : 0 Decenter Y : 0
Order : Decenter then tilt Tilt About X : -47.9
Surface 15 : COORDBRK Tilt About Y : 0
Decenter X : 0 Tilt About Z : 0
Decenter Y : 0 Order : Decenter then tilt
Tilt About X : 0 Surface 23 : COORDBRK
Tilt About Y : 0 Decenter X : 0
Tilt About Z : 0 Decenter Y : 0
SURFACE DATA DETAIL:
Surface OBJ : STANDARD
Surface 1 : STANDARD
Aperture : Circular Obscuration
Minimum Radius : 0
Maximum Radius : 0.6549285
Surface STO : STANDARD
Aperture : Circular Aperture
Minimum Radius : 0.6549285
Maximum Radius : 1e+010
Surface 3 : STANDARD
Surface 4 : STANDARD
Aperture : Circular Aperture
Minimum Radius : 0
Maximum Radius : 0.023631
Surface 5 : STANDARD
Aperture : Circular Aperture
Minimum Radius : 0
Maximum Radius : 0.026
Surface 6 : STANDARD
Aperture : Circular Aperture
Minimum Radius : 0
Maximum Radius : 0.026
Surface 7 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 180
Order : Decenter then tilt
Surface 8 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 0

```

```

Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 24 : STANDARD
Aperture : Circular Aperture
Minimum Radius : 0
Maximum Radius : 0.015
Surface 25 : STANDARD
Aperture : Circular Aperture
Minimum Radius : 0
Maximum Radius : 0.015
Surface 26 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 27 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : -47.9
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 28 : STANDARD
Aperture : Rectangular Aperture
X Half Width : 0.01745
Y Half Width : 0.02732
Surface 29 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : -47.9
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 30 : COORDBRK
Decenter X : 0
Decenter Y : 0.053770247
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 31 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 32 : STANDARD
Aperture : Circular Aperture
Minimum Radius : 0
Maximum Radius : 0.03153
Y- Decenter : -0.0537703
Surface 33 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 34 : COORDBRK
Decenter X : 0
Decenter Y : -0.053770247
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 35 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 11.6
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 36 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 37 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : -47.9
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 38 : STANDARD
Aperture : Rectangular Aperture
X Half Width : 0.031864
Y Half Width : 0.02548
X- Decenter : 0.014414
Surface 39 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : -47.9
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 40 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 41 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : -180
Order : Decenter then tilt
Surface 42 : STANDARD
Aperture : Rectangular Aperture
X Half Width : 0.0074
Y Half Width : 9.7e-005
Surface 43 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 44 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 0
Tilt About Y : -6
Tilt About Z : 0
Order : Decenter then tilt
Surface 45 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 46 : COORDBRK
Decenter X : -0.12577867
Decenter Y : 0
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Order : Decenter then tilt
Surface 47 : STANDARD
Aperture : Circular Aperture
Minimum Radius : 0
Maximum Radius : 0.08

```

X- Decenter	: 0.12577	X Half Width	: 0.071	Surface 63	: DGRATING
Surface 48	: COORDBRK	Y Half Width	: 0.16	Lines / Micron	: 0.075001875
Decenter X	: 0.12577867	Surface 56	: COORDBRK	Diffract Order	: 4
Decenter Y	: 0	Decenter X	: 0	Aperture	: Rectangular Aperture
Tilt About X	: 0	Decenter Y	: 0	X Half Width	: 0.103
Tilt About Y	: 0	Tilt About X	: -63.02	Y Half Width	: 0.093
Tilt About Z	: 0	Tilt About Y	: 0	Surface 64	: STANDARD
Order	: Decenter then tilt	Tilt About Z	: 0	Aperture	: Rectangular Aperture
Surface 49	: COORDBRK	Order	: Decenter then tilt	X Half Width	: 0.11
Decenter X	: 0	Surface 57	: COORDBRK	Y Half Width	: 0.1
Decenter Y	: 0	Decenter X	: 0	Surface 65	: COORDBRK
Tilt About X	: 0	Decenter Y	: 0	Decenter X	: 0
Tilt About Y	: 0	Tilt About X	: 0	Decenter Y	: 0
Tilt About Z	: 0	Tilt About Y	: 0	Tilt About X	: -14.1022
Order	: Decenter then tilt	Tilt About Z	: 0	Tilt About Y	: 0
Surface 50	: COORDBRK	Order	: Decenter then tilt	Tilt About Z	: 0
Decenter X	: 0	Surface 58	: COORDBRK	Order	: Tilt then decenter
Decenter Y	: 0	Decenter X	: 0	Surface 66	: COORDBRK
Tilt About X	: 0	Decenter Y	: 0	Decenter X	: 0
Tilt About Y	: 0	Tilt About X	: 0	Decenter Y	: 0
Tilt About Z	: 0	Tilt About Y	: 5	Tilt About X	: 0
Order	: Decenter then tilt	Tilt About Z	: 0	Tilt About Y	: 0
Surface 51	: COORDBRK	Order	: Decenter then tilt	Tilt About Z	: -90
Decenter X	: 0	Surface 59	: COORDBRK	Order	: Decenter then tilt
Decenter Y	: 0	Decenter X	: 0	Surface 67	: COORDBRK
Tilt About X	: 0	Decenter Y	: 0	Decenter X	: 0
Tilt About Y	: 5	Tilt About X	: 0	Decenter Y	: 0
Tilt About Z	: 0	Tilt About Y	: 0	Tilt About X	: 0
Order	: Decenter then tilt	Tilt About Z	: 0	Tilt About Y	: 0
Surface 52	: COORDBRK	Order	: Decenter then tilt	Tilt About Z	: 0
Decenter X	: 0	Surface 60	: COORDBRK	Order	: Decenter then tilt
Decenter Y	: 0	Decenter X	: 0	Surface 68	: COORDBRK
Tilt About X	: 0	Decenter Y	: 0	Decenter X	: 0
Tilt About Y	: 0	Tilt About X	: 0	Decenter Y	: 0.22849426
Tilt About Z	: 0	Tilt About Y	: 0	Tilt About X	: 0
Order	: Decenter then tilt	Tilt About Z	: 0	Tilt About Y	: 0
Surface 53	: COORDBRK	Order	: Decenter then tilt	Tilt About Z	: 0
Decenter X	: 0	Surface 61	: COORDBRK	Order	: Decenter then tilt
Decenter Y	: 0	Decenter X	: 0	Surface 69	: COORDBRK
Tilt About X	: 63.02	Decenter Y	: 0	Decenter X	: 0
Tilt About Y	: 0	Tilt About X	: 0	Decenter Y	: 0
Tilt About Z	: 0	Tilt About Y	: 0	Tilt About X	: 6.6632999
Order	: Decenter then tilt	Tilt About Z	: 90	Tilt About Y	: 0
Surface 54	: DGRATING	Order	: Decenter then tilt	Tilt About Z	: 0
Lines / Micron	: 0.0232	Surface 62	: COORDBRK	Order	: Decenter then tilt
Diffract Order	: 67	Decenter X	: 0	Surface 70	: STANDARD
Aperture	: Rectangular Aperture	Decenter Y	: 0	Aperture	: Elliptical Aperture
X Half Width	: 0.066	Tilt About X	: -35.89783	X Half Width	: 0.125
Y Half Width	: 0.156	Tilt About Y	: 0	Y Half Width	: 0.11
Surface 55	: STANDARD	Tilt About Z	: 0	Y- Decenter	: -0.22499999
Aperture	: Rectangular Aperture	Order	: Tilt then decenter	Surface 71	: COORDBRK

Decenter X	:	0	Tilt About Z	:	0	Tilt About X	:	0
Decenter Y	:	0	Order	:	Decenter then tilt	Tilt About Y	:	0
Tilt About X	:	0	Surface 79	:	COORDBRK	Tilt About Z	:	0
Tilt About Y	:	0	Decenter X	:	0	Order	:	Decenter then tilt
Tilt About Z	:	0	Decenter Y	:	0	Surface 87	:	COORDBRK
Order	:	Decenter then tilt	Tilt About X	:	-1.389563	Decenter X	:	0
Surface 72	:	COORDBRK	Tilt About Y	:	0	Decenter Y	:	0
Decenter X	:	0	Tilt About Z	:	0	Tilt About X	:	0
Decenter Y	:	0.006294235	Order	:	Decenter then tilt	Tilt About Y	:	0
Tilt About X	:	0	Surface 80	:	STANDARD	Tilt About Z	:	0
Tilt About Y	:	0	Aperture	:	Elliptical Aperture	Order	:	Decenter then tilt
Tilt About Z	:	0	X Half Width	:	0.13	Surface 88	:	COORDBRK
Order	:	Decenter then tilt	Y Half Width	:	0.08	Decenter X	:	3.5944788e-006
Surface 73	:	COORDBRK	Surface 81	:	COORDBRK	Decenter Y	:	0
Decenter X	:	0	Decenter X	:	0	Tilt About X	:	0
Decenter Y	:	0	Decenter Y	:	0	Tilt About Y	:	0
Tilt About X	:	-0.12782381	Tilt About X	:	1.389563	Tilt About Z	:	0
Tilt About Y	:	0	Tilt About Y	:	0	Order	:	Decenter then tilt
Tilt About Z	:	0	Tilt About Z	:	0	Surface 89	:	COORDBRK
Order	:	Decenter then tilt	Order	:	Decenter then tilt	Decenter X	:	0
Surface 74	:	STANDARD	Surface 82	:	COORDBRK	Decenter Y	:	0.046702877
Aperture	:	Elliptical Aperture	Decenter X	:	0	Tilt About X	:	0
X Half Width	:	0.02	Decenter Y	:	0.0086412849	Tilt About Y	:	0
Y Half Width	:	0.026	Tilt About X	:	0	Tilt About Z	:	0
Y- Decenter	:	-0.054000001	Tilt About Y	:	0	Order	:	Decenter then tilt
Surface 75	:	COORDBRK	Tilt About Z	:	0	Surface 90	:	COORDBRK
Decenter X	:	0	Order	:	Decenter then tilt	Decenter X	:	0
Decenter Y	:	0	Surface 83	:	COORDBRK	Decenter Y	:	0
Tilt About X	:	0.12782381	Decenter X	:	0	Tilt About X	:	-2.8476251
Tilt About Y	:	0	Decenter Y	:	0	Tilt About Y	:	0
Tilt About Z	:	0	Tilt About X	:	0	Tilt About Z	:	0
Order	:	Decenter then tilt	Tilt About Y	:	0	Order	:	Decenter then tilt
Surface 76	:	COORDBRK	Tilt About Z	:	0	Surface 91	:	COORDBRK
Decenter X	:	0	Order	:	Decenter then tilt	Decenter X	:	0
Decenter Y	:	-0.006294235	Surface 84	:	COORDBRK	Decenter Y	:	0
Tilt About X	:	0	Decenter X	:	0	Tilt About X	:	0
Tilt About Y	:	0	Decenter Y	:	0.033101144	Tilt About Y	:	-0.045513461
Tilt About Z	:	0	Tilt About X	:	0	Tilt About Z	:	0
Order	:	Decenter then tilt	Tilt About Y	:	0	Order	:	Decenter then tilt
Surface 77	:	COORDBRK	Tilt About Z	:	0	Surface 92	:	COORDBRK
Decenter X	:	0	Order	:	Decenter then tilt	Decenter X	:	0
Decenter Y	:	0	Surface 85	:	COORDBRK	Decenter Y	:	0
Tilt About X	:	0	Decenter X	:	0	Tilt About X	:	0
Tilt About Y	:	0	Decenter Y	:	0	Tilt About Y	:	0
Tilt About Z	:	0	Tilt About X	:	0	Tilt About Z	:	4.54
Order	:	Decenter then tilt	Tilt About Y	:	0	Order	:	Decenter then tilt
Surface 78	:	COORDBRK	Tilt About Z	:	0	Surface IMA	:	STANDARD
Decenter X	:	0	Order	:	Decenter then tilt	Aperture	:	Rectangular Aperture
Decenter Y	:	-0.0086412849	Surface 86	:	COORDBRK	X Half Width	:	0.013824
Tilt About X	:	0	Decenter X	:	0	Y Half Width	:	0.013824
Tilt About Y	:	0	Decenter Y	:	-0.033101087			

Appendix C: System/Prescription Data: Global Vertex Data

File : D:\lenses\nirspec\endtoend\Tmakck24.zmx
 Title: NIRSPEC ON KECK
 Date : SUN NOV 8 1998

LENS NOTES:

Notes...

GLOBAL VERTEX COORDINATES, ORIENTATIONS, AND ROTATION/OFFSET
 MATRICES:

Reference Surface: 1

Surf	R11	R12	R13	X	Y	Z
	R21	R22	R23			
	R31	R32	R33			
1	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
2	1.000000	0.000000	0.000000	0.000000	0.000000	16.650000
	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
3	1.000000	0.000000	0.000000	0.000000	0.000000	1.255015
	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
4	1.000000	0.000000	0.000000	0.000000	0.000000	19.150000
	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
5	1.000000	0.000000	0.000000	0.000000	0.000000	19.180633
	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
6	1.000000	0.000000	0.000000	0.000000	0.000000	19.188133
	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
7	-1.000000	0.000000	0.000000	0.000000	0.000000	19.248133
	-0.000000	-1.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000

8	-1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	-0.000000	-1.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	1.000000	0.000000	1.000000	19.248133
9	-1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	-0.000000	-0.670427	-0.741976	-0.741976	0.000000	0.000000
	0.000000	-0.741976	0.670427	0.670427	0.000000	19.248133
10	-1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	-0.000000	-0.670427	-0.741976	-0.741976	0.000000	0.000000
	0.000000	-0.741976	0.670427	0.670427	0.000000	19.248133
11	-1.000000	-0.000000	0.000000	0.000000	0.000000	0.000000
	-0.000000	0.101056	-0.994881	-0.994881	0.000000	0.000000
	0.000000	-0.994881	-0.101056	-0.101056	0.000000	19.248133
12	-1.000000	-0.000000	0.000000	0.000000	0.000000	-0.000000
	-0.000000	0.101056	-0.994881	-0.994881	0.302528	0.000000
	0.000000	-0.994881	-0.101056	-0.101056	19.278863	0.000000
13	-1.000000	0.000000	0.000000	0.000000	0.000000	-0.000000
	-0.000000	-0.101056	-0.994881	-0.994881	0.302528	0.000000
	0.000000	-0.994881	0.101056	0.101056	19.278863	0.000000
14	-1.000000	0.000000	0.000000	0.000000	0.000000	-0.000000
	-0.000000	-0.101056	-0.994881	-0.994881	0.294400	0.000000
	0.000000	-0.994881	0.101056	0.101056	19.198844	0.000000
15	-1.000000	0.000000	0.000000	0.000000	0.000000	-0.000000
	-0.000000	-0.101056	-0.994881	-0.994881	0.294400	0.000000
	0.000000	-0.994881	0.101056	0.101056	19.198844	0.000000
16	-1.000000	0.000000	0.000000	0.000000	0.000000	-0.000000
	-0.000000	-0.101056	-0.994881	-0.994881	0.298464	0.000000
	0.000000	-0.994881	0.101056	0.101056	19.198431	0.000000
17	-1.000000	0.000000	0.000000	0.000000	0.000000	-0.000000
	-0.000000	-0.101056	-0.994881	-0.994881	0.298464	0.000000
	0.000000	-0.994881	0.101056	0.101056	19.198431	0.000000
18	-1.000000	0.000000	0.000000	0.000000	0.000000	-0.000000
	-0.000000	-0.101056	-0.994881	-0.994881	0.306592	0.000000
	0.000000	-0.994881	0.101056	0.101056	19.278450	0.000000
19	-1.000000	0.000000	0.000000	0.000000	0.000000	-0.000000
	-0.000000	-0.101056	-0.994881	-0.994881	0.302528	0.000000
	0.000000	-0.994881	0.101056	0.101056	19.278863	0.000000

20	-1.000000	-0.000000	0.000000	0.000000	33	-1.000000	0.000000	-0.000000	-0.000000
	-0.000000	0.670427	-0.741976	-0.000000		-0.000000	-0.101056	0.994881	0.214169
	0.000000	-0.741976	-0.670427	19.309593		0.000000	0.994881	0.101056	19.539041
21	-1.000000	-0.000000	0.000000	0.000000	34	-1.000000	0.000000	-0.000000	-0.000000
	-0.000000	0.670427	-0.741976	-0.000000		-0.000000	-0.101056	0.994881	0.216886
	0.000000	-0.741976	-0.670427	19.309593		0.000000	0.994881	0.101056	19.485270
22	-1.000000	-0.000000	-0.000000	0.000000	35	-1.000000	-0.000000	-0.000000	-0.000000
	-0.000000	1.000000	0.000000	-0.000000		-0.000000	0.101056	0.994881	0.216886
	0.000000	0.000000	-1.000000	19.309593		0.000000	0.994881	-0.101056	19.485270
23	-1.000000	-0.000000	-0.000000	0.000000	36	-1.000000	-0.000000	-0.000000	-0.000000
	-0.000000	1.000000	0.000000	-0.000000		-0.000000	0.101056	0.994881	0.216886
	0.000000	0.000000	-1.000000	19.413239		0.000000	0.994881	-0.101056	19.485270
24	-1.000000	-0.000000	-0.000000	0.000000	37	-1.000000	0.000000	-0.000000	0.000000
	-0.000000	1.000000	0.000000	-0.000000		-0.000000	-0.670427	0.741976	-0.000000
	0.000000	0.000000	-1.000000	19.413239		0.000000	0.741976	0.670427	19.507300
25	-1.000000	-0.000000	-0.000000	0.000000	38	-1.000000	0.000000	-0.000000	0.000000
	-0.000000	1.000000	0.000000	-0.000000		-0.000000	-0.670427	0.741976	-0.000000
	0.000000	0.000000	-1.000000	19.415239		0.000000	0.741976	0.670427	19.507300
26	-1.000000	-0.000000	-0.000000	0.000000	39	-1.000000	0.000000	0.000000	0.000000
	-0.000000	1.000000	0.000000	-0.000000		-0.000000	-1.000000	-0.000000	-0.000000
	0.000000	0.000000	-1.000000	19.463239		0.000000	-0.000000	1.000000	19.507300
27	-1.000000	-0.000000	-0.000000	0.000000	40	-1.000000	0.000000	0.000000	0.000000
	-0.000000	0.670427	0.741976	-0.000000		-0.000000	-1.000000	-0.000000	-0.000000
	0.000000	0.741976	-0.670427	19.463239		0.000000	-0.000000	1.000000	19.556732
28	-1.000000	-0.000000	-0.000000	0.000000	41	1.000000	0.000000	0.000000	0.000000
	-0.000000	0.670427	0.741976	-0.000000		0.000000	1.000000	-0.000000	-0.000000
	0.000000	0.741976	-0.670427	19.463239		-0.000000	0.000000	1.000000	19.556732
29	-1.000000	0.000000	-0.000000	0.000000	42	1.000000	0.000000	0.000000	0.000000
	-0.000000	-0.101056	0.994881	-0.000000		0.000000	1.000000	-0.000000	-0.000000
	0.000000	0.994881	0.101056	19.463239		-0.000000	0.000000	1.000000	19.556732
30	-1.000000	0.000000	-0.000000	-0.000000	43	1.000000	0.000000	0.000000	0.000000
	-0.000000	-0.101056	0.994881	0.211452		0.000000	1.000000	-0.000000	-0.000000
	0.000000	0.994881	0.101056	19.538765		-0.000000	0.000000	1.000000	20.760028
31	-1.000000	0.000000	-0.000000	-0.000000	44	0.994522	0.000000	-0.104528	0.000000
	-0.000000	-0.101056	0.994881	0.211452		-0.000000	1.000000	-0.000000	-0.000000
	0.000000	0.994881	0.101056	19.538765		0.104528	0.000000	0.994522	20.760028
32	-1.000000	0.000000	-0.000000	-0.000000	45	0.994522	0.000000	-0.104528	0.000000
	-0.000000	-0.101056	0.994881	0.214169		-0.000000	1.000000	-0.000000	-0.000000
	0.000000	0.994881	0.101056	19.539041		0.104528	0.000000	0.994522	20.760028

46	0.994522	0.000000	-0.104528	-0.125434	59	0.997564	0.000000	0.069756	0.125434
	-0.000000	1.000000	-0.000000	-0.000000		0.000000	1.000000	-0.000000	-0.000000
	0.104528	0.000000	0.994522	20.750158		-0.069756	0.000000	0.997564	19.566601
47	0.994522	0.000000	-0.104528	-0.125434	60	0.997564	0.000000	0.069756	0.125434
	-0.000000	1.000000	-0.000000	-0.000000		0.000000	1.000000	-0.000000	-0.000000
	0.104528	0.000000	0.994522	20.750158		-0.069756	0.000000	0.997564	19.566601
48	0.994522	0.000000	-0.104528	-0.000345	61	-0.000000	-0.997564	0.069756	0.205654
	-0.000000	1.000000	-0.000000	-0.000000		1.000000	-0.000000	-0.000000	-0.000000
	0.104528	0.000000	0.994522	20.763305		0.000000	0.069756	0.997564	20.713800
49	0.994522	0.000000	-0.104528	-0.000345	62	-0.000000	-0.848992	-0.528406	0.205654
	-0.000000	1.000000	-0.000000	-0.000000		1.000000	0.000000	-0.000000	-0.000000
	0.104528	0.000000	0.994522	20.763305		0.000000	-0.528406	0.848992	20.713800
50	0.994522	0.000000	-0.104528	0.125434	63	-0.000000	-0.848992	-0.528406	0.205654
	-0.000000	1.000000	-0.000000	-0.000000		1.000000	0.000000	-0.000000	-0.000000
	0.104528	0.000000	0.994522	19.566601		0.000000	-0.528406	0.848992	20.713800
51	0.999848	0.000000	-0.017452	0.125434	64	-0.000000	-0.848992	-0.528406	0.205654
	-0.000000	1.000000	-0.000000	-0.000000		1.000000	0.000000	-0.000000	-0.000000
	0.017452	0.000000	0.999848	19.566601		0.000000	-0.528406	0.848992	20.713800
52	0.999848	0.000000	-0.017452	0.125434	65	-0.000000	-0.694658	-0.719340	0.205654
	-0.000000	1.000000	-0.000000	-0.000000		1.000000	0.000000	-0.000000	-0.000000
	0.017452	0.000000	0.999848	19.566601		0.000000	-0.719340	0.694658	20.713800
53	0.999848	-0.015553	-0.007918	0.125434	66	0.694658	-0.000000	-0.719340	0.205654
	-0.000000	0.453679	-0.891165	-0.000000		-0.000000	1.000000	-0.000000	-0.000000
	0.017452	0.891029	0.453610	19.566601		0.719340	0.000000	0.694658	20.713800
54	0.999848	-0.015553	-0.007918	0.125434	67	0.694658	-0.000000	-0.719340	0.205654
	-0.000000	0.453679	-0.891165	-0.000000		-0.000000	1.000000	-0.000000	-0.000000
	0.017452	0.891029	0.453610	19.566601		0.719340	0.000000	0.694658	20.713800
55	0.999848	-0.015553	-0.007918	0.125434	68	0.694658	-0.000000	-0.719340	0.457423
	-0.000000	0.453679	-0.891165	-0.000000		-0.000000	1.000000	-0.000000	0.228494
	0.017452	0.891029	0.453610	19.566601		0.719340	0.000000	0.694658	20.470670
56	0.999848	0.000000	-0.017452	0.125434	69	0.694658	-0.083468	-0.714481	0.457423
	-0.000000	1.000000	-0.000000	-0.000000		-0.000000	0.993245	-0.116035	0.228494
	0.017452	0.000000	0.999848	19.566601		0.719340	0.080604	0.689966	20.470670
57	0.999848	0.000000	-0.017452	0.125434	70	0.694658	-0.083468	-0.714481	0.457423
	-0.000000	1.000000	-0.000000	-0.000000		-0.000000	0.993245	-0.116035	0.228494
	0.017452	0.000000	0.999848	19.566601		0.719340	0.080604	0.689966	20.470670
58	0.997564	0.000000	0.069756	0.125434	71	0.694658	-0.083468	-0.714481	0.457423
	0.000000	1.000000	-0.000000	-0.000000		-0.000000	0.993245	-0.116035	0.228494
	-0.069756	0.000000	0.997564	19.566601		0.719340	0.080604	0.689966	20.470670

72	0.694658	-0.083468	-0.714481	0.220898	85	0.694658	-0.083468	-0.714481	0.275704
	-0.000000	0.993245	-0.116035	0.196419		-0.000000	0.993245	-0.116035	0.232309
	0.719340	0.080604	0.689966	20.699079		0.719340	0.080604	0.689966	20.646154
73	0.694658	-0.081874	-0.714666	0.220898	86	0.694658	-0.083468	-0.714481	0.278467
	-0.000000	0.993502	-0.113818	0.196419		-0.000000	0.993245	-0.116035	0.199431
	0.719340	0.079065	0.690144	20.699079		0.719340	0.080604	0.689966	20.643486
74	0.694658	-0.081874	-0.714666	0.220898	87	0.694658	-0.083468	-0.714481	0.278467
	-0.000000	0.993502	-0.113818	0.196419		-0.000000	0.993245	-0.116035	0.199431
	0.719340	0.079065	0.690144	20.699079		0.719340	0.080604	0.689966	20.643486
75	0.694658	-0.083468	-0.714481	0.220898	88	0.694658	-0.083468	-0.714481	0.220298
	-0.000000	0.993245	-0.116035	0.196419		-0.000000	0.993245	-0.116035	0.189984
	0.719340	0.080604	0.689966	20.699079		0.719340	0.080604	0.689966	20.699664
76	0.694658	-0.083468	-0.714481	0.221423	89	0.694658	-0.083468	-0.714481	0.216400
	-0.000000	0.993245	-0.116035	0.190167		-0.000000	0.993245	-0.116035	0.236371
	0.719340	0.080604	0.689966	20.698572		0.719340	0.080604	0.689966	20.703428
77	0.694658	-0.083468	-0.714481	0.221423	90	0.694658	-0.047870	-0.717746	0.216400
	-0.000000	0.993245	-0.116035	0.190167		-0.000000	0.997783	-0.066547	0.236371
	0.719340	0.080604	0.689966	20.698572		0.719340	0.046227	0.693118	20.703428
78	0.694658	-0.083468	-0.714481	0.460062	91	0.694088	-0.047870	-0.718297	0.216400
	-0.000000	0.993245	-0.116035	0.220223		-0.000053	0.997783	-0.066547	0.236371
	0.719340	0.080604	0.689966	20.468121		0.719891	0.046227	0.692547	20.703428
79	0.694658	-0.066118	-0.716295	0.460062	92	0.688121	-0.102660	-0.718297	0.216400
	-0.000000	0.995767	-0.091914	0.220223		0.078927	0.994657	-0.066547	0.236371
	0.719340	0.063849	0.691717	20.468121		0.721291	-0.010901	0.692547	20.703428
80	0.694658	-0.066118	-0.716295	0.460062	93	0.688121	-0.102660	-0.718297	0.216400
	-0.000000	0.995767	-0.091914	0.220223		0.078927	0.994657	-0.066547	0.236371
	0.719340	0.063849	0.691717	20.468121		0.721291	-0.010901	0.692547	20.703428
81	0.694658	-0.083468	-0.714481	0.460062					
	-0.000000	0.993245	-0.116035	0.220223					
	0.719340	0.080604	0.689966	20.468121					
82	0.694658	-0.083468	-0.714481	0.459341					
	-0.000000	0.993245	-0.116035	0.228806					
	0.719340	0.080604	0.689966	20.468818					
83	0.694658	-0.083468	-0.714481	0.459341					
	-0.000000	0.993245	-0.116035	0.228806					
	0.719340	0.080604	0.689966	20.468818					
84	0.694658	-0.083468	-0.714481	0.275704					
	-0.000000	0.993245	-0.116035	0.232309					
	0.719340	0.080604	0.689966	20.646154					