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Parametric Tolerances for the WIYN Wide Field Corrector

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Introduction

The optical design of the WIYN telescope calls for corrective optics to be placed in the light path to one of the Nasmyth foci. The Wide Field Corrector (WFC), which was designed by Charles Harmer, is a two element lens 50 cm in diameter. Both elements are of fused silica and have all-spherical optical surfaces. When installed in the telescope the WFC will provide image correction for a one degree diameter field of view with a bandpass from 330 nanometers to 1.53 microns.

The location of the WFC is shown relative to the telescope reflective optics in figure 1. Figures 2 and 3 show the WFC lens elements, and figure 4 shows spot diagrams for rays traced through the corrector. These spot diagrams show the combined images of five wavelengths of light (at 330, 365, 436, 852 and 1529 nanometers) at five locations in the field (on axis and at 0.125, 0.25, 0.375, and 0.5° off axis). The RMS and geometric (ie 100% encircled energy) image radii are listed in the figure.

Parametric tolerances for the WFC consist of the radii of curvature of the four surfaces, lens thicknesses and wedges angles. Full fabrication tolerances must also consider the quality of the optical surfaces as departures from ideal surfaces.

Parametric Tolerancing Procedure

The Zemax ray tracing program was used to determine the effect of changes in each of the eight fabrication parameters. To do this the parameter was changed a small amount, then the Zemax optimization package was used to determine a new best position along the telescope optical axis for the WFC. The radius of curvature of the focal plane was also optimized.

During the optimization the total track length from the primary to the secondary and from the secondary to the focal plane was held constant. In all cases a corrector shift on the order of 5 mm or less was sufficient to largely compensate for perturbations to the lens parameters.

In each case the nominal design was used as a starting point for the optimization. This was done for repeatability so that any particular optimized configuration would not be influenced by the optimization history.

Perturbations in six of the parameters (the four radii and two thicknesses) maintain an axi-symmetric optic, while the two wedge angle result in non-symmetric optics. For the symmetrical cases, after optimization the RMS image radii were recorded for five filed positions in five colors as described earlier. The results are presented graphically in figures 5 and 6, which show the rms image radius for the five field positions and the average image radius as a function of variation in surface radius of curvature. Note that in all cases the image diameter at the edge of the field (circular tic marks) is most influenced by parametric variations, while the average value is relatively unchanged for small departures from the design values.

For the case of the two wedge angles, spot diameters were recorded at 17 points in the one degree field arranged on orthogonal axes.

The influence of each parameter on image size and on focal plane curvature was determined from the data. In cases where the slope was not symmetric with respect to positive or negative departures from the nominal design, the larger of the two influences was recorded. These were used to assign tolerances to each parameter.

The tolerances were balanced to assign the largest allowance to parameters which had the strongest influence. Other parameters such as wedge and thicknesses, which are relatively easy to hold, were set to values that can be met with standard shop practices.

Parametric Tolerances

The influence functions and tolerances are given in table 1 attached. As a "spot" check, the corrector design was perturbed by randomly setting all the lens parameters to positive or negative extremes of the tolerance range. Two such random settings yielded average image size of 9.65 and 9.244 microns RMS radius (0.153 and 0.146 arcseconds FWHM respectively). This compares to a nominal design value of 8.984 microns RMS radius (0.142 FWHM). This constitutes an image degradations of 0.007 and 0.004 arcseconds FWHM, well within the image error budget allowance of 0.04 arcseconds FWHM.

Table 1: Summary of influence functions & tolerances for WIYN Wide Field Corrector

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Total image allowance: 0.04 fwhm = 0.0472 RMS = 2.5252 Microns RMS Radius

Focal surface allowance: +/-.1 mm change in sagitta = +/- 155 mm change in radius

8 parameters for fabricating the two lenses:

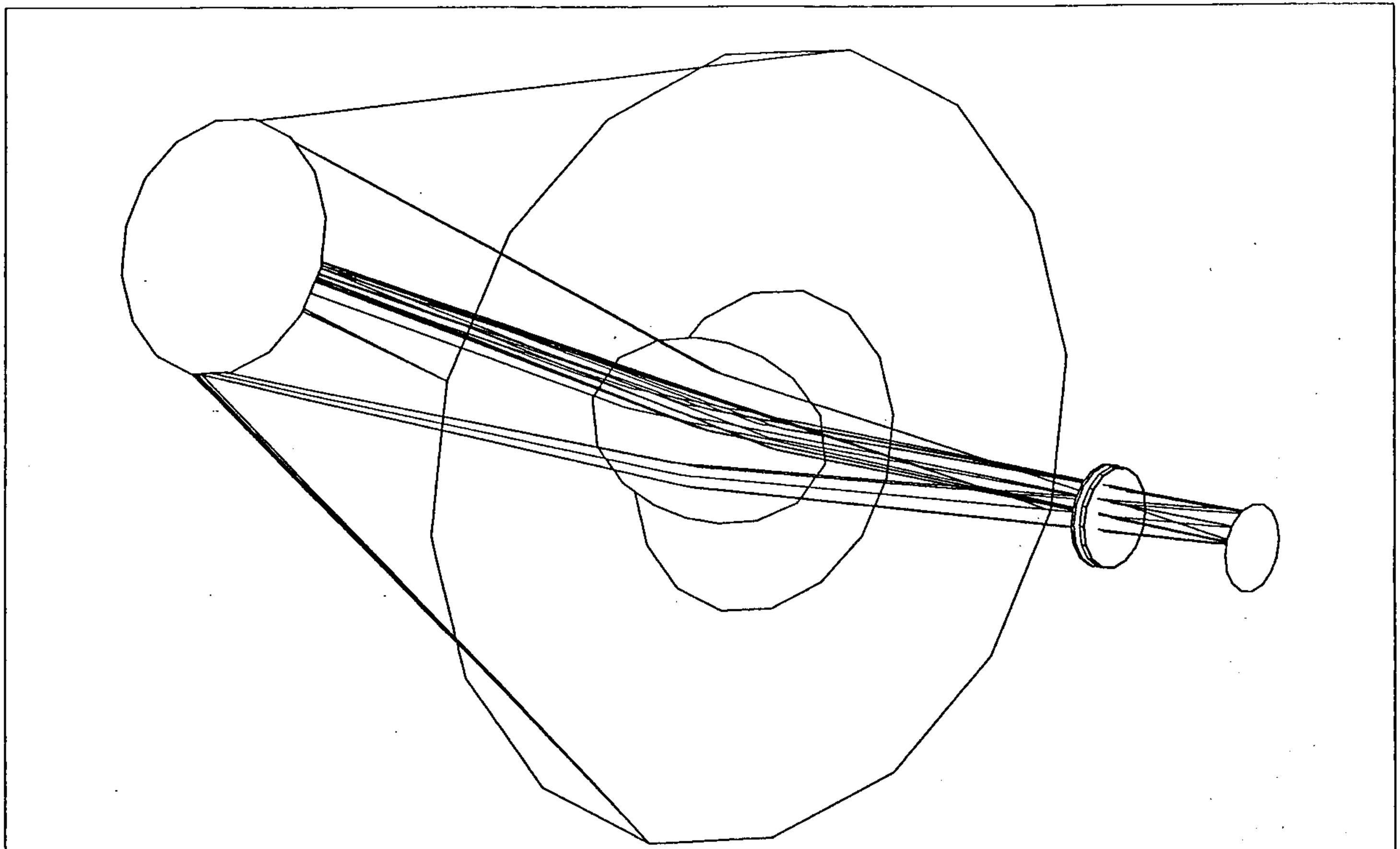
Parameter	Nominal Value	Unit	Image influence (microns)	% of total influence	Tolerance	Image Contribution (microns)	Image Contribution FWHM	Focal Radius Influence	Focal Radius Contribution
R1	1424.044	mm	0.31	1.59%	2	0.62000	0.0098	-18	-36
R2	1954.931	mm	0.112	0.58%	3	0.33600	0.0053	14	42
R3	599.77	mm	3.3	16.96%	0.5	1.65000	0.0261	95	47.5
R4	519.991	mm	4.2	21.59%	0.4	1.68000	0.0266	124	49.6
T1	20	mm	0.016	0.08%	0.2	0.00320	0.0001	-30	-6
T2	20	mm	1.196	6.15%	0.2	0.23920	0.0038	62	12.4
Wedge 1-2	0	deg	0.55	2.83%	0.01	0.00550	0.0001	0	0
Wedge 3-4	0	deg	9.77	50.22%	0.01	0.09770	0.0015	0	0
			19.454	100.00%					

RSS (microns RMS radius) 2.47164

Arcseconds RMS 0.04620

FWHM 0.03915

RSS of focal surface radius (mm) 89.2534



SOLID MODEL

WIDE FIELD CORRECTOR
FRI MAY 07 1993

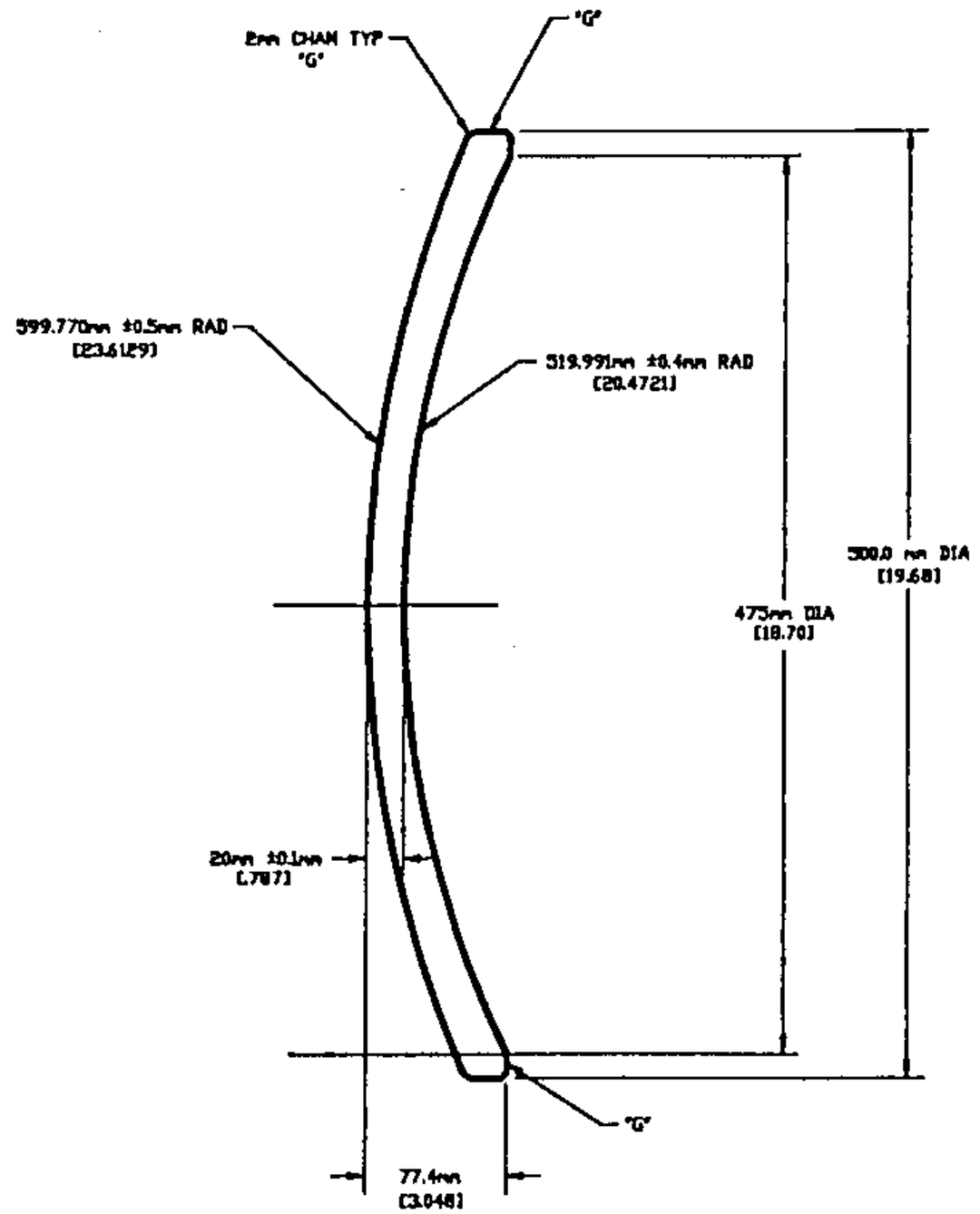
WIYN PROJECT
WISCONSIN, INDIANA, YALE, NOAO

FIGURE 1

NOTES: UNLESS OTHERWISE NOTED

1. REMOVE ALL BURRS AND SHARP EDGES
2. MACHINED SURFACE ROUGHNESS 125
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. MATERIAL: SILICA NO. SIO2
   Nd 1.4585 ±0.001 V 67.8 ±0.2%
   STRIAE GRADE 2/25 .5nm/cm ANNEAL
   HOM. DN 3E-06
   (CORNING 7990 GRADE 2D OR EQUIVALENT)
5. PITCH POLISH TO TEST PLATE WITHIN POWER AND IRREGULARITY SPECIFIED.
6. SURFACE QUALITY: PER SPECIFICATION
7. "G" = FINE GRIND
8. NO STRIAE TO BE VISIBLE OVER C.A. IN NORMAL SCHLIEREN

REVISIONS					
ZONE	LTR	REVISIONS	ECO	DATE	BY



DECIMALS .XX ± .03 .XXX ± .010	FRACTIONS ±	ANGULAR ± 0°30'
NEXT ASSEMBLY	NAME: WIDE FIELD CORRECTOR LENS #2	DWG NO: 0820
		WYN TEL.
SIZE: A/2		3506.0005619D

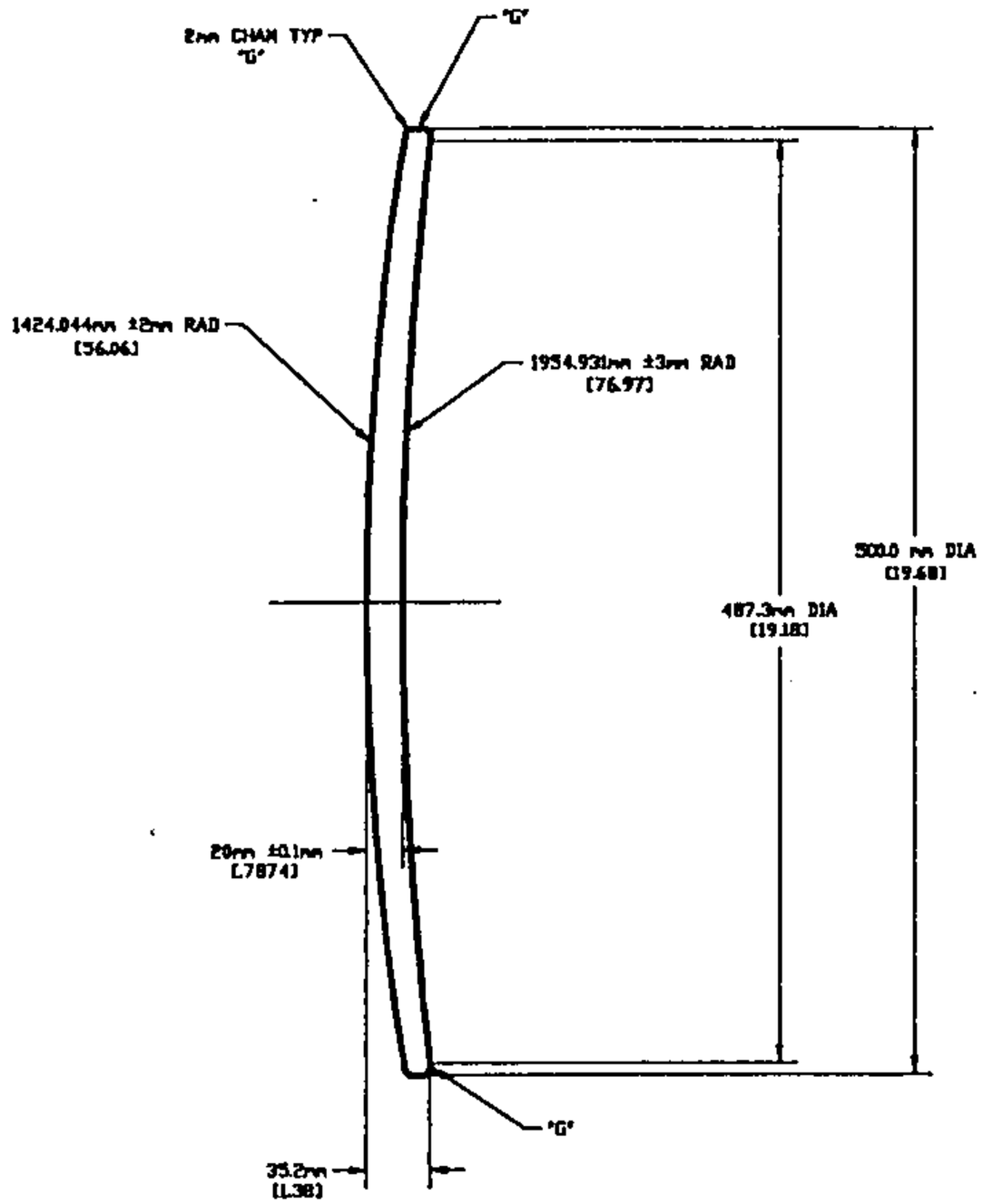
FIGURE 2

NOTES: UNLESS OTHERWISE NOTED

1. REMOVE ALL BURRS AND SHARP EDGES
2. MACHINED SURFACE ROUGHNESS 125
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. MATERIAL: SILICA NO1 SIDE
   Nd 1.45985 ±0.001 V 67.8 ±0.2%
   STRIAE GRADE 2/B25 .5mm/cm ANNEAL
   HOM: DN 2E-06
   (CORNING 7990 GRADE 2B OR EQUIVALENT)
5. PITCH POLISH TO TEST PLATE WITHIN
   POWER AND IRREGULARITY SPECIFIED.
6. SURFACE QUALITY: PER SPECIFICATION
7. "G" = FINE GRIND
8. NO STRIAE TO BE VISIBLE OVER C.A.
   IN NORMAL SCHLIEREN

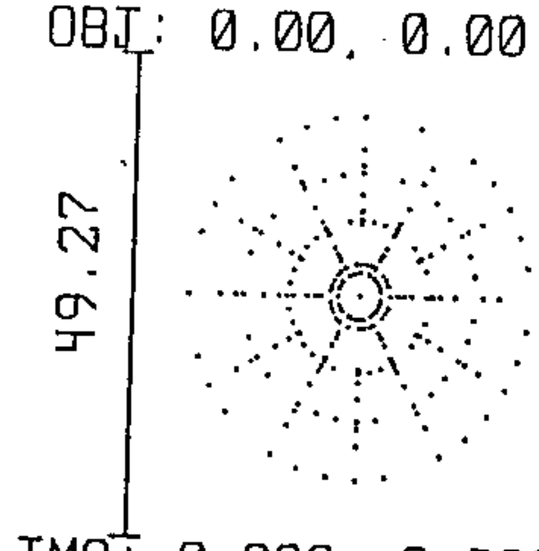
REVISIONS

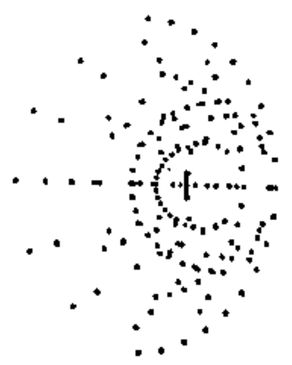
ZONE	LTR	REVISION	ECR	DATE	BY	APVD



NEXT ASSEMBLY	NAME: WIDE FIELD CORRECTOR LENS #1	0820
		WIYN TEL.
1/2		3506.0005618D

FIGURE 3





IMA: 68.110, 68.110 MM

SPOT DIAGRAM

WIDE FIELD CORRECTOR
FRI MAY 07 1993 UNITS ARE MICRONS.

FIELD	:	1	2	3	4	5
RMS RADIUS	:	10.31	8.83	7.47	6.25	12.06
GEO RADIUS	:	18.43	17.72	14.93	12.39	24.64
SCALE BAR	:	49.27		REFERENCE	:	CHIEF RAY

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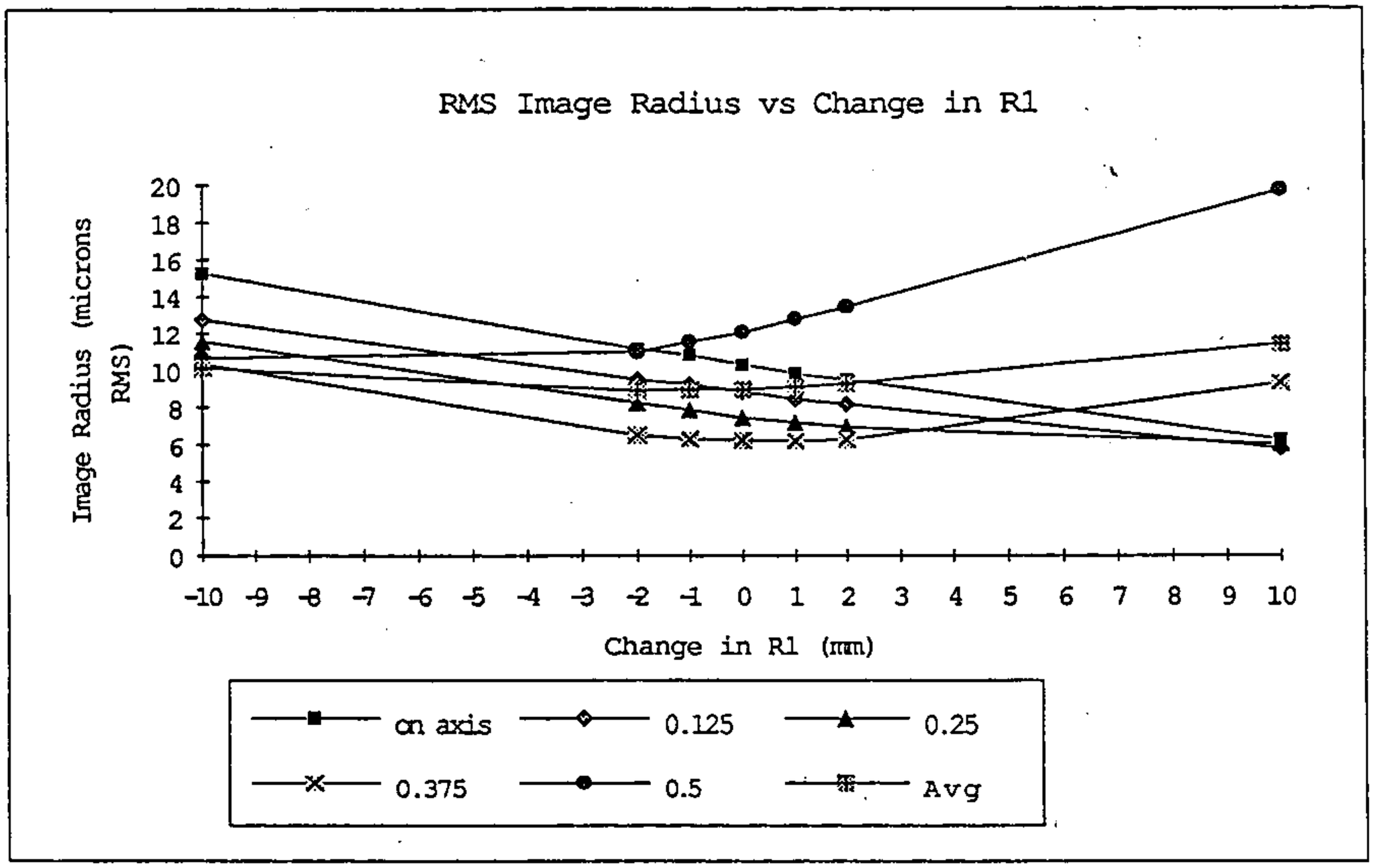
FIGURE 4


RMS Image Radius vs Change in R1
Image Radius (microns RMS)
20
18
16
14
12
10
8
6
4
2
0
-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10
Change in R1 (mm)
on axis
0.125
0.25
0.375
0.5
Avg

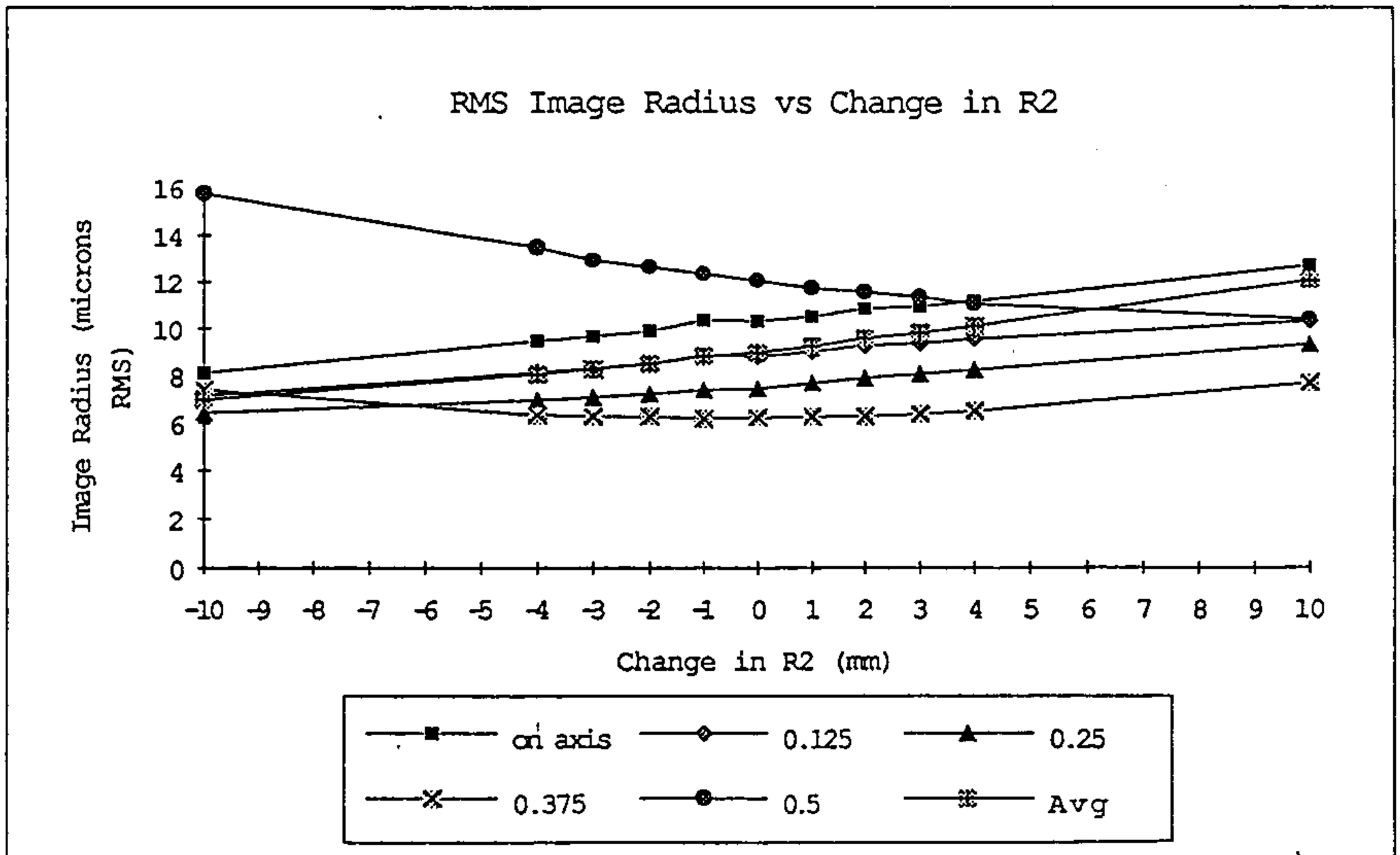
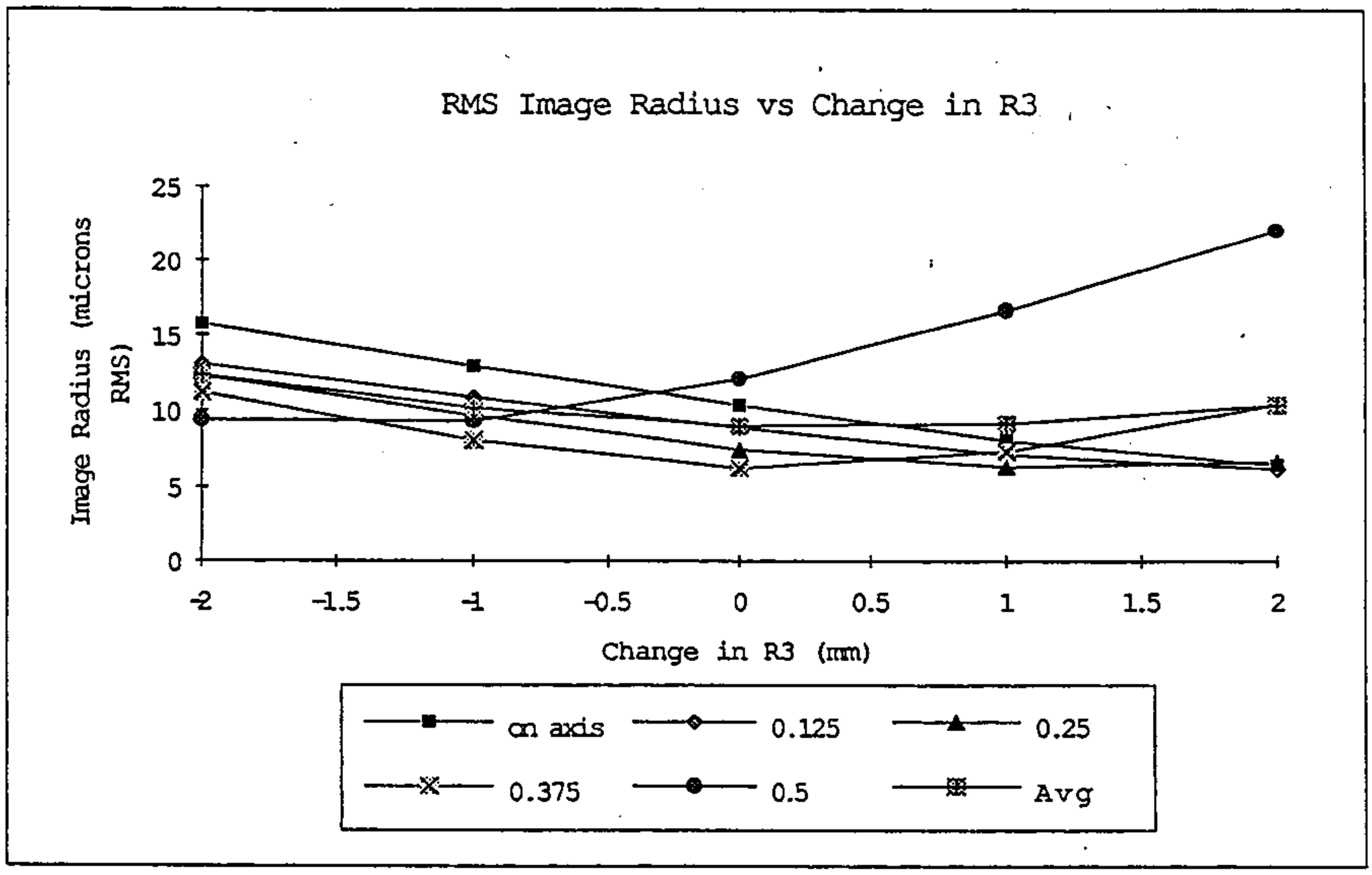

RMS Image Radius vs Change in R2
Image Radius (microns RMS)
16
14
12
10
8
6
4
2
0
-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10
Change in R2 (mm)
on axis
0.125
0.25
0.375
0.5
Avg

FIGURE 5


RMS Image Radius vs Change in R3
Image Radius (microns RMS)
25
20
15
10
5
0
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Change in R3 (mm)
on axis
0.125
0.25
0.375
0.5
Avg

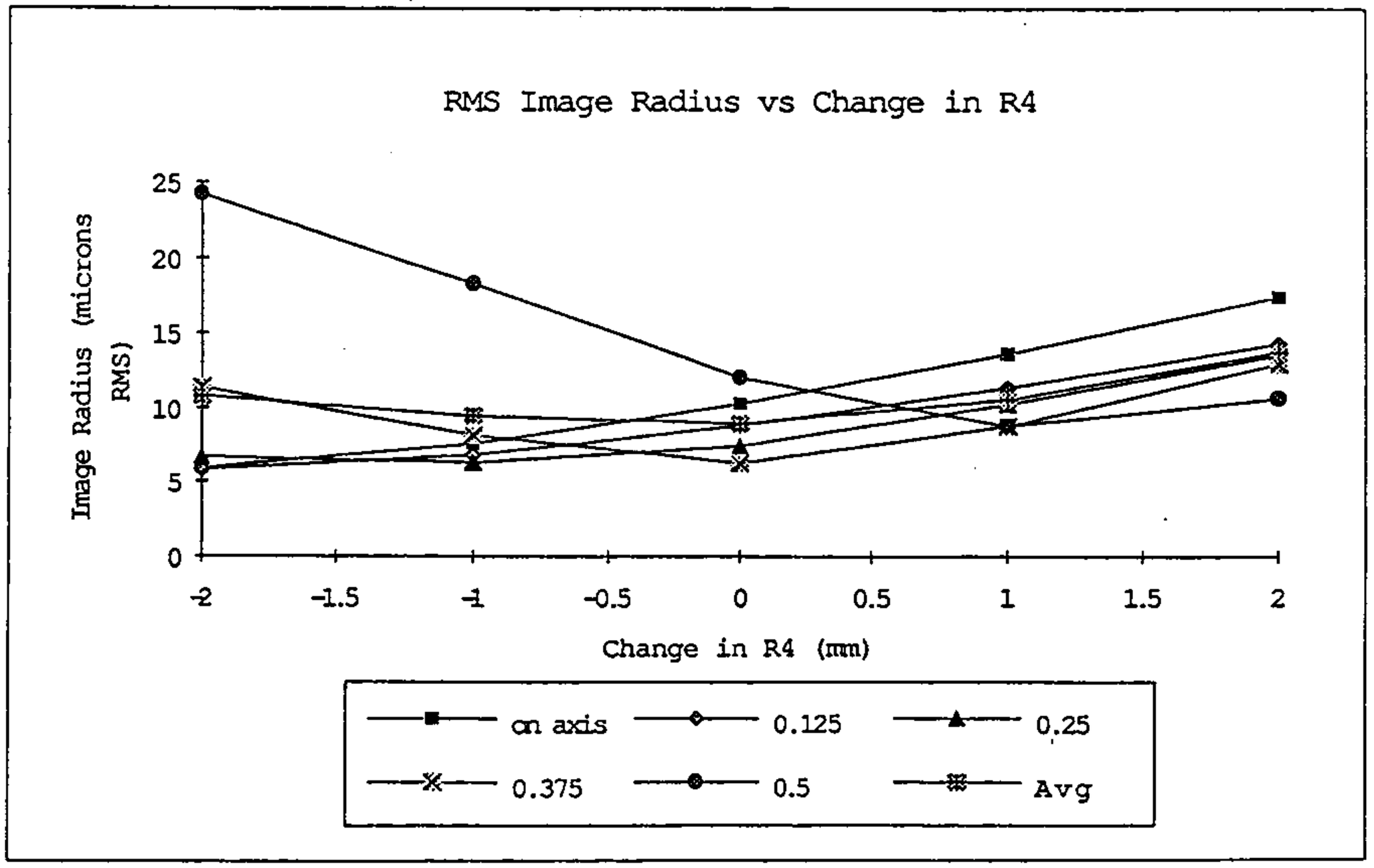

RMS Image Radius vs Change in R4
Image Radius (microns RMS)
25
20
15
10
5
0
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Change in R4 (mm)
on axis
0.125
0.25
0.375
0.5
Avg

FIGURE 6