ERIM
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

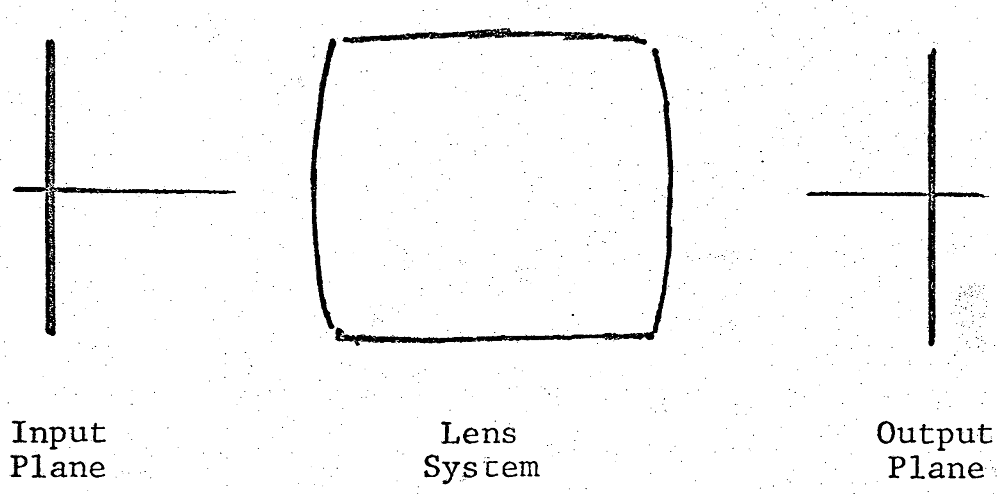
19 November 1976

MEMORANDUM TO: VLA Processor

FROM: Ivan Cindrich

SUBJECT: Fourier Transform Lens Design

Several lens design companies were contacted to establish preliminarily the design feasibility of a high performance Fourier transform lens system to be used in the arrangement shown below



An initial response received from one company, the Applied Optics Division of Perkin-Elmer at Costa Mesa, was very encouraging and some of their lens design properties are summarized here. Their design P5637A has the general physical arrangement shown in Figure 1.

The peak phase error (input plane equivalent) obtained from ray trace computations for 316 input plane points is shown in Figure 2 for the axis along which these errors are a maximum. The input plane is 110 mm in diameter and the data was obtained for several spatial input frequencies (or diffraction angles). It can be seen that for an input aperture of 50 mm (-25 to +25) and for frequencies up to about 50 c/mm that the phase error is less than $\frac{\lambda}{50}$. For the 110 mm aperture (-50 to +50) and for frequencies up to 110 c/mm the phase error is less than about $\frac{\lambda}{10}$.

These data are for an output Fourier transform "plane", i.e., a flat surface. As can be seen from the data of Figure 2, the phase error curves have a linear component which will give rise to a very small change of scale factor at the output plane that can be removed by calibration. If such calibration is included in the use of such a lens system then the equivalent phase error can be reduced to about $\frac{\lambda}{100}$ for an input data aperture of 50 mm and 50 c/mm bandwidth. For a 110 mm and 110 c/mm bandwidth input data aperture such calibration would likely allow $\frac{\lambda}{20}$ performance.

Follow-up on this lens design requires further analysis (impulse response computations) and consideration of manufacturing quality (surface errors and scattering noise) as well as cost estimation.

The two-dimensional phase error distributions from which the data of Figure 2 was prepared are given in Figures 3 through 7 for the cases of zero, 55, 77, 95 and 110 c/mm input frequencies, respectively. The phase error is given in fractions of a wavelength for 316 equally spaced locations in a circular input aperture.

IC:sd

[redacted]

PRELIMINARY DESIGN
PR 77-5637 11/10/76

THE PERKIN-ELMER CORPORATION
2930 So. Bristol Street
Costa Mesa, Calif. 92626

ESIGN NO.P5637A, FOURIER LENS FOR 110 C/MM BANDWIDTH, 5145A WAVELENGTH, 1370-MM EFL. 110976-143

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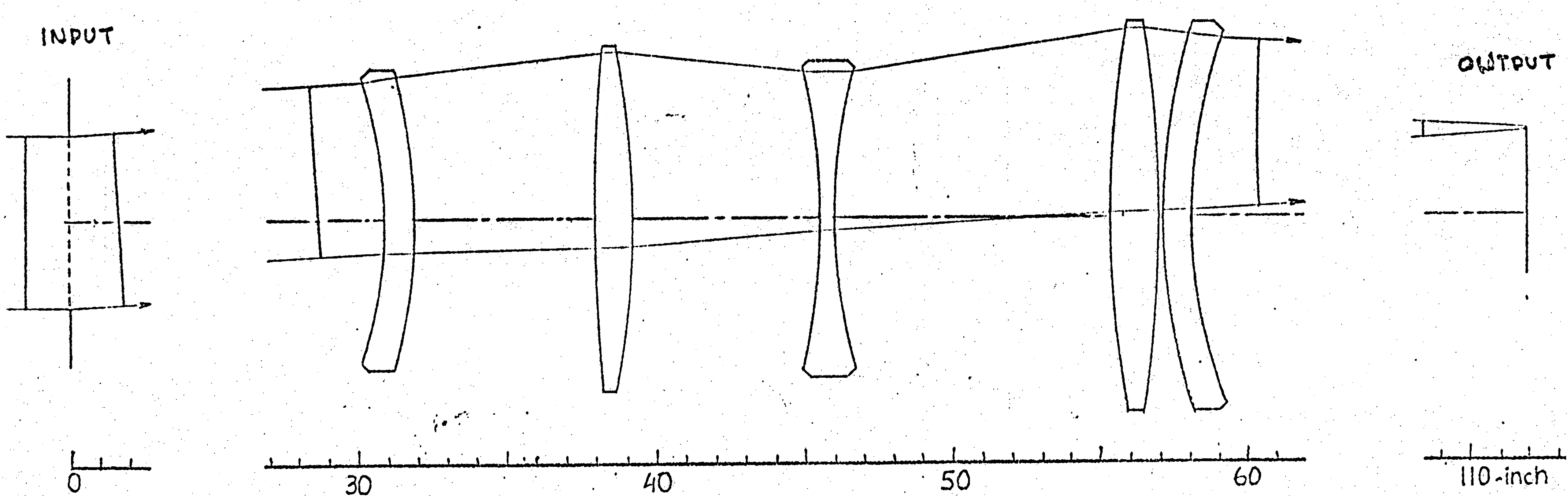
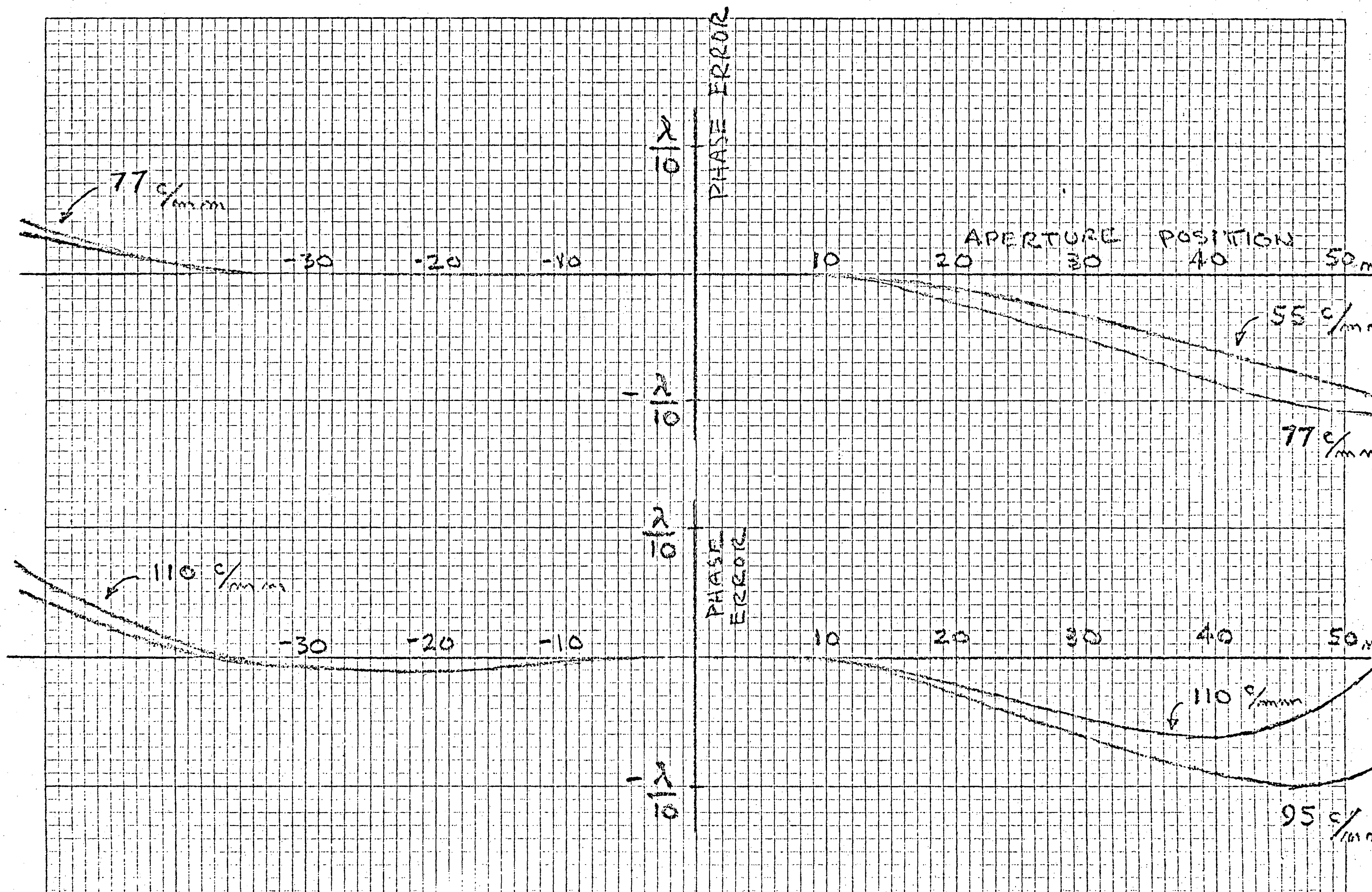
0 0 0 3.062000=PM(1) 0.000000=SIN UM(1) 0.000000=HP(1) .056686=TAN UP(1)
.51450 .48613 .65627 25.4MM=UNIT OF LENG

FIGURE 1



FIRST ORDER PARAMETERS ON MERIDIONAL PLANE

BJECT DSTNCE	ENTR.PUP.DIST	FRST.PPAL.PNT	EQV.FCL.LNGTH	SCND.PPAL.PNT	EXT.PUP.DSTNC	IMAGE DISTNCE
9999.999996	-31.701727	24.941549	54.000000	-.423205	1156.753164	53.576795
BJECT HEIGHT	ENTR.PUP.SIZE	OBJT.SPCE.FNO	INF.EQUIV.FNO	IMGE.SPCE.FNO	EXT.PUPL.SIZE	IMAGE HEIGHT
9999.999996	6.124000	999999.999996	-8.817766	-8.817766	125.108372	3.061033
AGNIFICATION	SEMIANG.FIELD	FRNT.VTX.DIST	BARREL LENGTH	BACK VTX.DIST	SEMIANG.FIELD	DEMAGNIFICATN
0.000000	3.244385	80.971948	27.395153	999999.999996	-.158981	0.000000
PT.STOP SIZE	APT.STOP DIST	FROM SRFCE.NO	TRACK LENGTH	FLD.STOP SIZE	FLD.STOP DIST	FROM.SRFCE.NO
6.124000	-31.701727	1.000000	999999.999996	6.122066	53.576795	10.000000



PEAK PHASE ERROR EQUIVALENT AT INPUT
FOR PE FT LENS DESIGN P5637A (11/16/76)

WAVE ABERRA N (WAVELENGTH UNITS)

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                    -.00 -.00 -.00 -.00 -.00 -.00
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FIGURE 3

WAVE ABERRATION (WAVELENGTH UNITS)

							-.09	-.09	-.09	-.09	-.09	-.09							
					-.08	-.08	-.08	-.08	-.08	-.08	-.08	-.08	-.08	-.08					
			-.06	-.07	-.07	-.07	-.07	-.06	-.06	-.06	-.06	-.07	-.07	-.07	-.07	-.06			
		-.06	-.06	-.06	-.05	-.05	-.05	-.05	-.05	-.05	-.05	-.05	-.05	-.05	-.06	-.06	-.06		
		-.05	-.05	-.05	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.05	-.05	-.05		
	-.04	-.04	-.04	-.03	-.03	-.03	-.03	-.02	-.02	-.02	-.02	-.03	-.03	-.03	-.03	-.04	-.04	-.04	
	-.03	-.03	-.03	-.03	-.02	-.02	-.02	-.02	-.01	-.01	-.02	-.02	-.02	-.02	-.03	-.03	-.03	-.03	
-.02	-.02	-.02	-.02	-.02	-.02	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.02	-.02	-.02	-.02	-.02	-.02
-.02	-.02	-.02	-.01	-.01	-.01	-.01	-.01	-.00	-.00	-.00	-.00	-.01	-.01	-.01	-.01	-.01	-.02	-.02	-.02
-.01	-.01	-.01	-.01	-.01	-.01	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01
-.00	-.00	-.00	-.01	-.01	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.01	-.01	-.00	-.00	-.00
.00	.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	.00	.00
.01	.01	.00	.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	.00	.00	.01	.01
	.01	.01	.01	.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	.00	.01	.01	.01	
	.01	.01	.01	.01	.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	.00	.01	.01	.01	.01	
		.02	.01	.01	.01	.00	.00	-.00	-.00	-.00	-.00	.00	.00	.01	.01	.01	.02		
		.02	.02	.02	.01	.01	.01	.01	.00	.00	.01	.01	.01	.01	.02	.02	.02		
			.03	.02	.02	.02	.02	.01	.01	.01	.01	.02	.02	.02	.02	.03			
					.03	.03	.02	.02	.02	.02	.02	.02	.03	.03					
							.03	.03	.03	.03	.03	.03							

FIGURE 4 (55)

WAVE ABERRATION (WAVELENGTH UNITS)

							-.10	-.11	-.11	-.11	-.11	-.10							
					-.09	-.10	-.10	-.10	-.10	-.10	-.10	-.10	-.10	-.09					
			-.08	-.08	-.09	-.09	-.09	-.09	-.09	-.09	-.09	-.09	-.09	-.09	-.08	-.08			
		-.06	-.07	-.07	-.08	-.08	-.07	-.07	-.07	-.07	-.07	-.07	-.08	-.08	-.07	-.07	-.06		
		-.06	-.06	-.06	-.06	-.06	-.06	-.05	-.05	-.05	-.05	-.06	-.06	-.06	-.06	-.06	-.06		
	-.05	-.05	-.05	-.05	-.05	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.05	-.05	-.05	-.05	-.05	
	-.04	-.04	-.04	-.04	-.03	-.03	-.03	-.02	-.02	-.02	-.02	-.03	-.03	-.03	-.04	-.04	-.04	-.04	
-.03	-.03	-.03	-.03	-.02	-.02	-.02	-.01	-.01	-.01	-.01	-.01	-.01	-.02	-.02	-.02	-.03	-.03	-.03	-.03
-.02	-.02	-.02	-.02	-.02	-.01	-.01	-.01	-.00	-.00	-.00	-.00	-.01	-.01	-.01	-.02	-.02	-.02	-.02	-.02
-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.00	-.00	-.00	-.00	-.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.01
-.00	-.01	-.01	-.01	-.01	-.01	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.01	-.01	-.01	-.01	-.01	-.00
.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	.00
.01	.01	.00	-.00	-.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.00	-.00	-.00	.00	.01	.01
	.01	.01	.00	-.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.00	-.00	.00	.01	.01	
	.02	.01	.01	.00	-.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.00	-.00	.00	.01	.01	.02	
		.02	.01	.01	.00	-.00	-.00	-.01	-.01	-.01	-.01	-.00	-.00	.00	.01	.01	.02		
		.03	.02	.02	.01	.01	.00	-.00	-.00	-.00	-.00	.00	.01	.01	.02	.02	.03		
			.03	.03	.02	.02	.01	.01	.01	.01	.01	.01	.02	.02	.03	.03			
					.03	.03	.03	.02	.02	.02	.02	.03	.03	.03					
							.04	.04	.04	.04	.04	.04							

FIGURE 5 (77)

WAVE ABERRATION (WAVELENGTH UNITS)

							-.07	-.08	-.08	-.08	-.08	-.07							
					-.07	-.08	-.09	-.09	-.10	-.10	-.09	-.09	-.08	-.07					
			-.05	-.07	-.08	-.09	-.09	-.09	-.09	-.09	-.09	-.09	-.09	-.08	-.07	-.05			
		-.04	-.06	-.07	-.07	-.08	-.08	-.08	-.08	-.08	-.08	-.08	-.08	-.07	-.07	-.06	-.04		
		-.05	-.06	-.06	-.06	-.06	-.06	-.06	-.06	-.06	-.06	-.06	-.06	-.06	-.06	-.06	-.05		
	-.03	-.04	-.05	-.05	-.05	-.05	-.04	-.04	-.04	-.04	-.04	-.04	-.05	-.05	-.05	-.05	-.04	-.03	
	-.03	-.04	-.04	-.04	-.04	-.03	-.03	-.03	-.03	-.03	-.03	-.03	-.03	-.04	-.04	-.04	-.04	-.03	
-.02	-.02	-.03	-.03	-.03	-.02	-.02	-.02	-.01	-.01	-.01	-.01	-.02	-.02	-.02	-.03	-.03	-.03	-.02	-.02
-.01	-.02	-.02	-.02	-.02	-.02	-.01	-.01	-.01	-.00	-.00	-.01	-.01	-.01	-.02	-.02	-.02	-.02	-.02	-.01
-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.00	-.00	-.00	-.00	-.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.01
-.00	-.00	-.01	-.01	-.01	-.01	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.01	-.01	-.01	-.01	-.00	-.00
.01	.00	-.00	-.00	-.01	-.01	-.01	-.00	-.00	-.00	-.00	-.00	-.00	-.01	-.01	-.01	-.00	-.00	.00	.01
.01	.01	.00	-.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.00	-.00	.00	.01	.01
	.01	.01	.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.00	.00	.01	.01	
	.02	.01	.01	.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.00	.00	.01	.01	.02	
		.02	.02	.01	.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.00	.00	.01	.02	.02		
		.03	.03	.02	.01	.01	.00	-.00	-.00	-.00	-.00	.00	.01	.01	.02	.03	.03		
			.04	.03	.03	.02	.01	.01	.01	.01	.01	.01	.02	.03	.03	.04			
					.04	.04	.03	.03	.02	.02	.03	.03	.04	.04					
							.05	.05	.05	.05	.05	.05							

FIGURE 6 (95)

WAVE ABERRATION (WAVELENGTH UNITS)

							.02	.0	00	.00	.01	.02							
					.00	-.02	-.03	-.04	-.04	-.04	-.04	-.03	-.02	.00					
			.01	-.01	-.03	-.05	-.06	-.06	-.06	-.06	-.06	-.06	-.05	-.03	-.01	.01			
		.01	-.02	-.04	-.05	-.05	-.06	-.06	-.06	-.06	-.06	-.06	-.05	-.05	-.04	-.02	.01		
		-.01	-.03	-.04	-.05	-.05	-.05	-.05	-.05	-.05	-.05	-.05	-.05	-.05	-.04	-.03	-.01		
	-.00	-.02	-.03	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.04	-.03	-.02	-.00	
	-.01	-.02	-.03	-.03	-.03	-.03	-.03	-.03	-.02	-.02	-.03	-.03	-.03	-.03	-.03	-.03	-.02	-.01	
.01	-.01	-.02	-.02	-.02	-.02	-.02	-.02	-.01	-.01	-.01	-.01	-.02	-.02	-.02	-.02	-.02	-.02	-.01	.01
.00	-.01	-.01	-.02	-.02	-.01	-.01	-.01	-.01	-.00	-.00	-.01	-.01	-.01	-.01	-.02	-.02	-.01	-.01	.00
.01	-.00	-.01	-.01	-.01	-.01	-.01	-.00	-.00	-.00	-.00	-.00	-.00	-.01	-.01	-.01	-.01	-.01	-.00	.01
.01	.00	-.00	-.01	-.01	-.01	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.01	-.01	-.01	-.00	.00	.01
.01	.01	.00	-.00	-.00	-.01	-.01	-.00	-.00	-.00	-.00	-.00	-.00	-.01	-.01	-.00	-.00	.00	.01	.01
.02	.01	.01	.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.00	.00	.01	.01	.02
	.02	.01	.01	.00	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.00	.00	.01	.01	.02	
	.03	.02	.01	.01	-.00	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.01	-.00	.01	.01	.02	.03	
		.03	.02	.01	.01	.00	-.00	-.01	-.01	-.01	-.01	-.00	.00	.01	.01	.02	.03		
		.05	.04	.03	.02	.01	.01	.00	-.00	-.00	.00	.01	.01	.02	.03	.04	.05		
			.05	.05	.04	.03	.02	.02	.02	.02	.02	.02	.03	.04	.05	.05			
					.06	.05	.05	.04	.04	.04	.04	.05	.05	.06					
							.07	.07	.07	.07	.07	.07							

FIGURE 7 (110)