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ZERNIKE ABERRATIONS AND THEIR FAR FIELDS INTENSITIES.(U)
SEP 80 J HERRMANN

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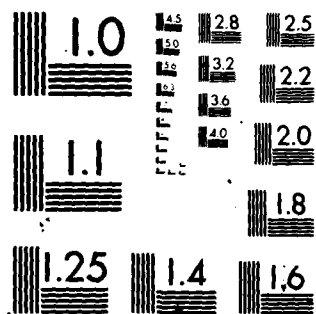
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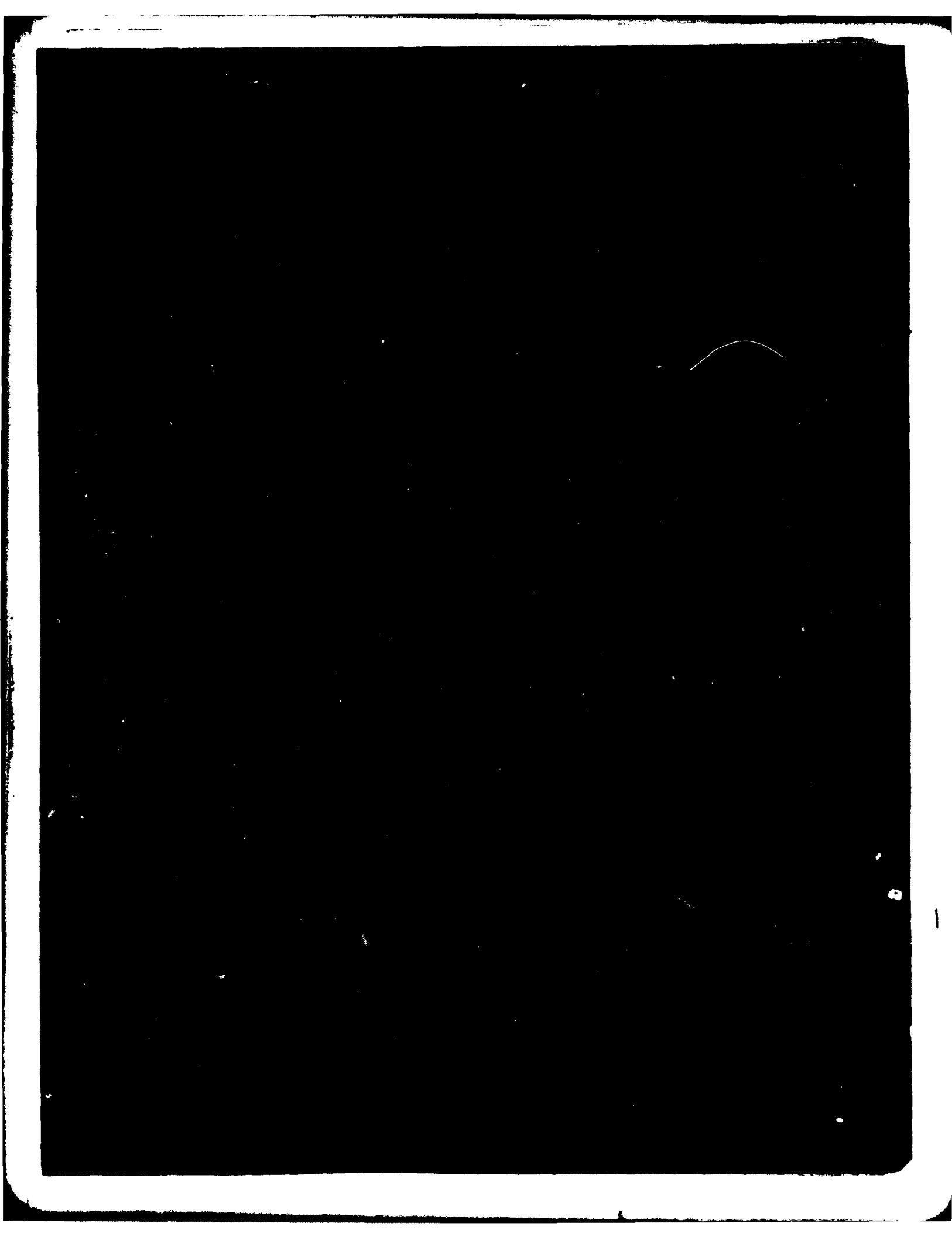


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LINCOLN LABORATORY

**ZERNIKE ABERRATIONS AND THEIR
FAR FIELD INTENSITIES**

J. HERRMANN
Group 55



TECHNICAL NOTE 1980-42

25 SEPTEMBER 1980

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LEXINGTON

MASSACHUSETTS

ZERNIKE ABERRATIONS AND THEIR FAR FIELD INTENSITIES.

We present in this report the phase of a wave front as described by the Zernike polynomials¹ and the corresponding intensities in the focal plane. All aberration up to $n=8$ are included. The numbering of the Zernike aberration is shown in Table I.

If the phase is expressed in terms of Zernike polynomials

$$\phi = \sum_{n=1}^{\infty} \sum_{m=0}^n A_{nm} R_n^m \cos m\theta$$

then the variance of the phase becomes

$$\langle \phi^2 \rangle = \sum_{n=1}^{\infty} \sum_{m=0}^n \frac{A_{nm}^2}{n+1} \frac{1 + \delta_{m0}}{2}$$

We present two sets of figures: The phase of the aberrations on the unit circle (in radians) and the intensity in the focal plane on a grid spaced by $R\lambda/D$ (with a contourline spacing of 2dB). A uniform intensity distribution is assumed for the aperture. The Strehl ratio (peak intensity) is indicated on each figure and also given in Table I. The extended Maréchal formula $\exp(-\langle \phi^2 \rangle)$ gives a value 0.674 for the Strehl ratio. Only the $\cos m\theta$ terms are presented because the $\sin m\theta$ terms can be obtained by a rotation. The assignment of the orders is in accordance with Ref. 1. Sec. 5.1 which uses $m + n$ for the order of wave aberrations.

The far field intensities were calculated using a discrete Fourier transform with a 256 by 256 computational mesh for most cases. For some aberrations ($k=16, 29, 37, 42$) 512 by 512 mesh points were used.

The most striking feature of the irradiances is the shape of the central lobe which is nearly constant for higher aberrations ($n \geq 5$).

¹M. Born and E. Wolf, Principles of Optics (Pergamon, New York, 1965), Sec. 9.2.

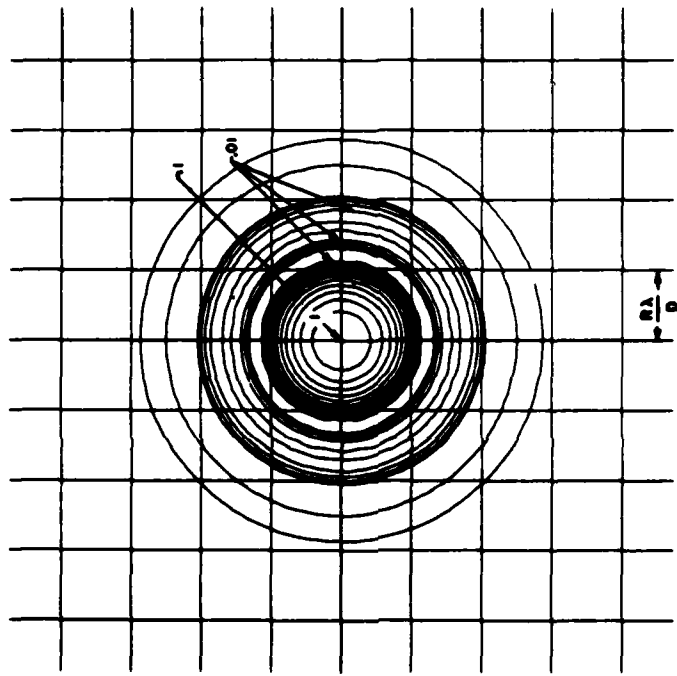
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Table I
Zernike Aberrations

k	n	m	$A_k^{a)}$	Strehl Ratio
2	1	1	1.257	-
4	2	0	1.088	0.653
5		2	1.539	0.667
7	3	1	1.777	0.651
9		3	"	0.671
11	4	0	1.405	0.627
12		2	1.987	0.645
14		4	"	0.675
16	5	1	2.177	0.644
18		3	"	0.634
20		5	"	0.677
22	6	0	1.662	0.604
23		2	2.351	0.622
25		4	"	0.638
27		6	"	0.681
29	7	1	2.513	0.641
31		3	"	0.625
33		5	"	0.640
35		7	"	0.684
37	8	0	1.885	0.626
38		2	2.666	0.614
40		4	"	0.596
42		6	"	0.654
44		8	"	0.689

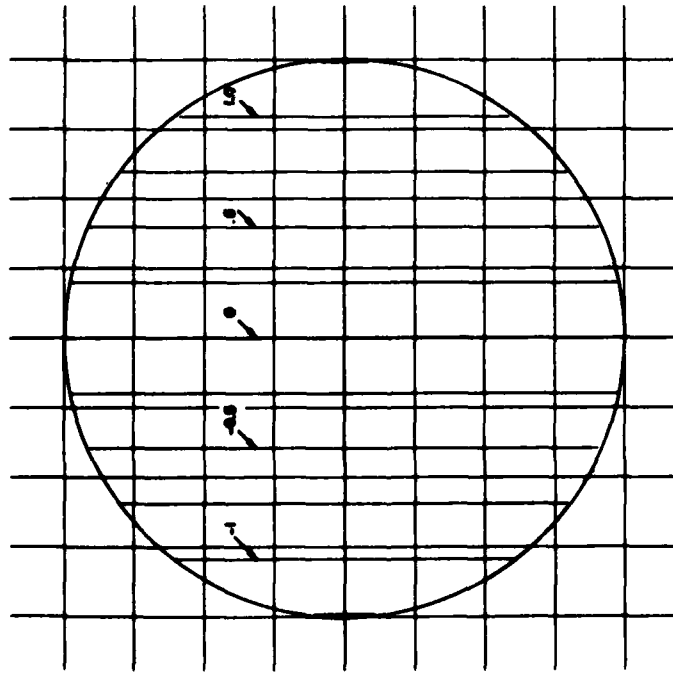
a) Chosen to give a mean-square phase deformation of $\lambda/10$ for each aberration.

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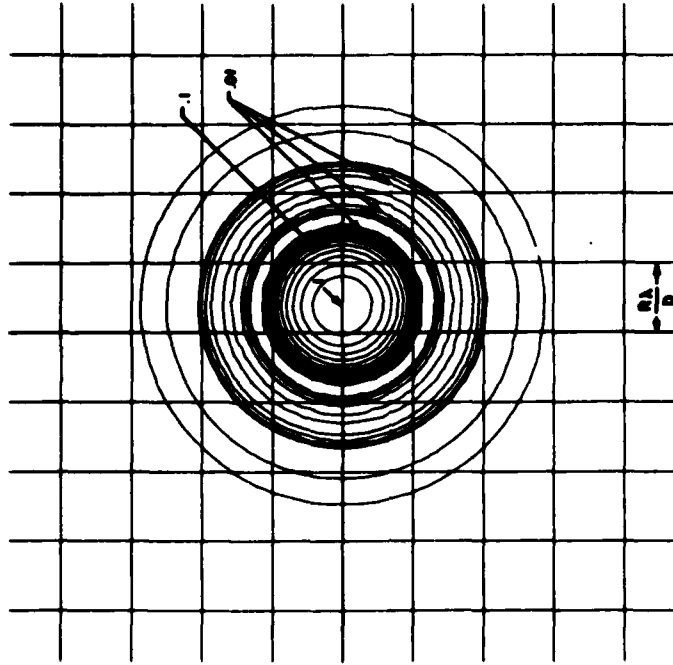
REFERENCE INTENSITY

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PHASE

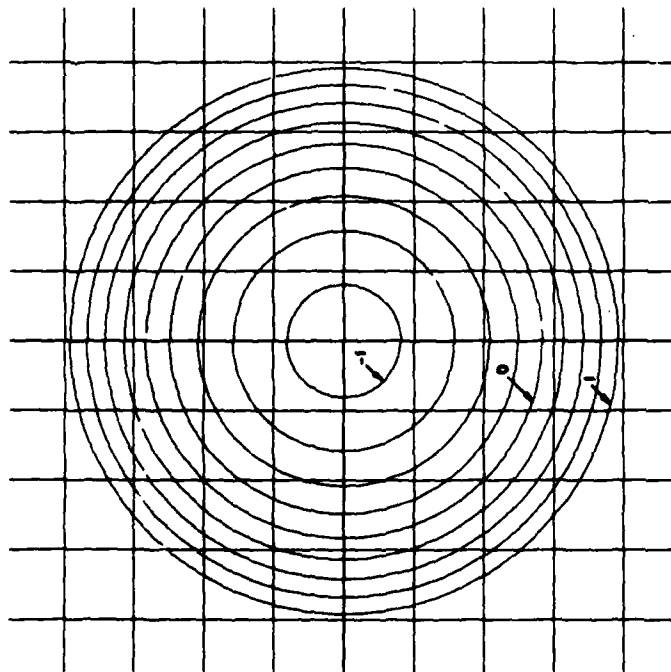
$k=2, n=1, m=1$



INTENSITY

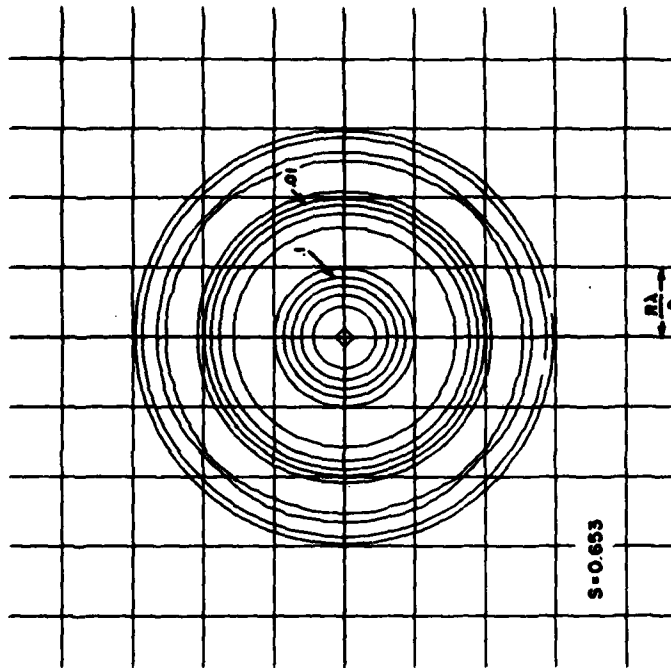
TILT

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PHASE

$k=4, n=2, m=0$



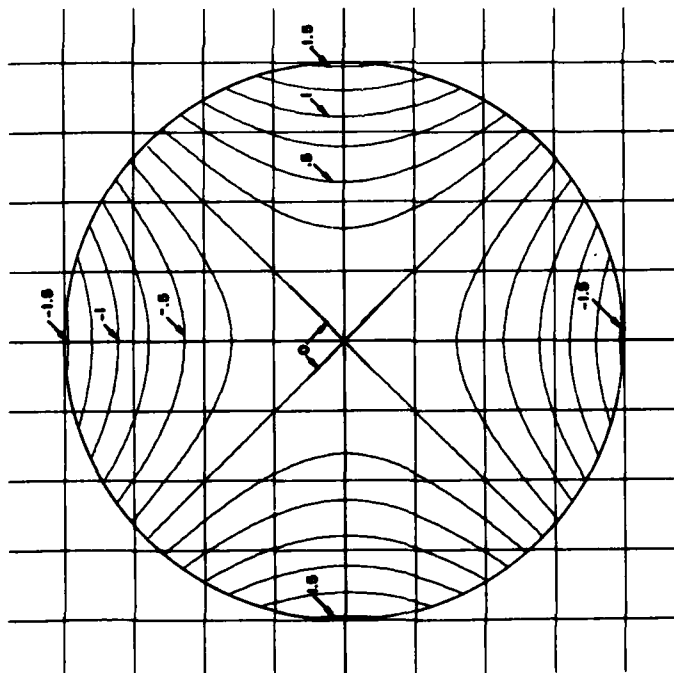
INTENSITY

FOCUS

$S=0.653$

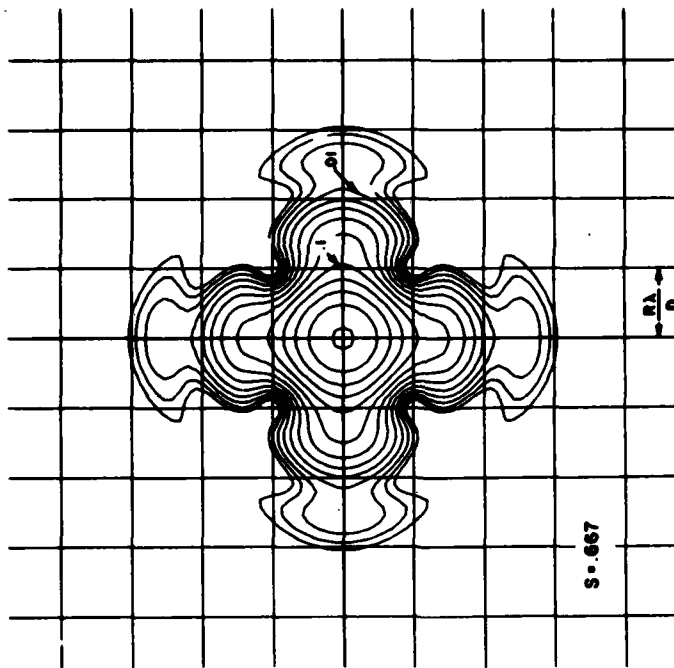
$\frac{R_1}{0}$

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PHASE

$k=5, n=2, m=2$



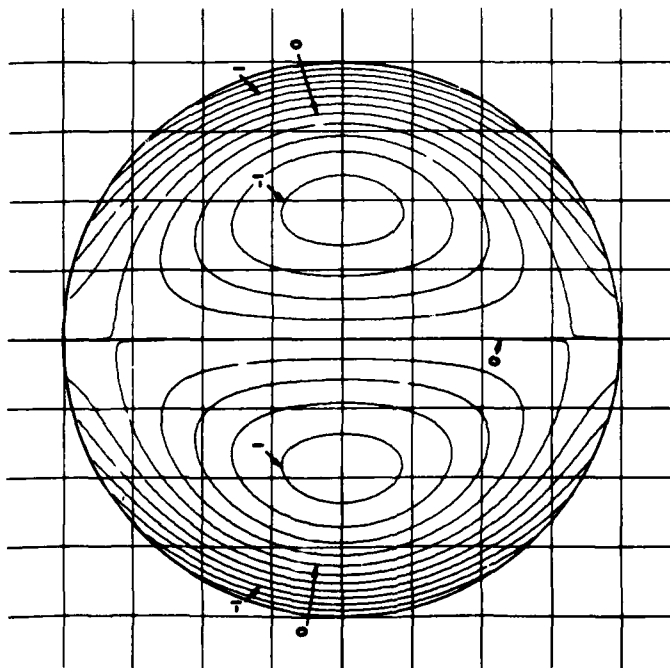
INTENSITY

ASTIGMATISM

$S=.667$

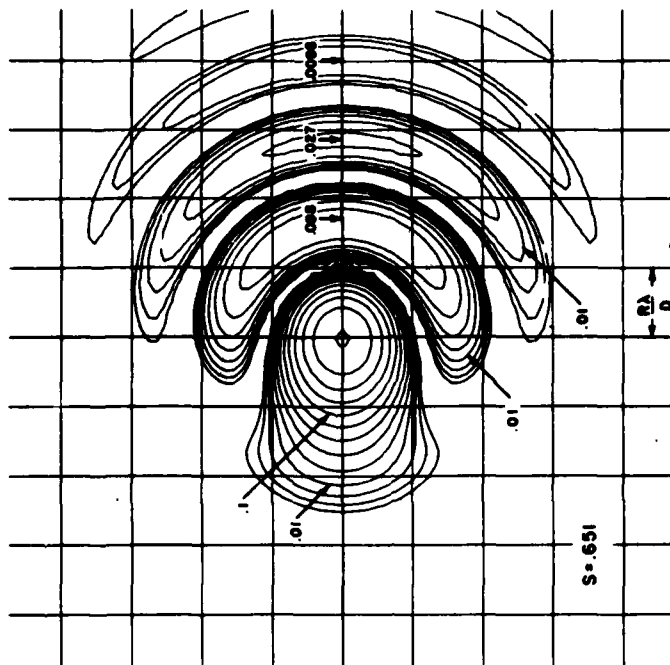
$\frac{NA}{\lambda}$

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PHASE

$k=7, n=3, m=1$

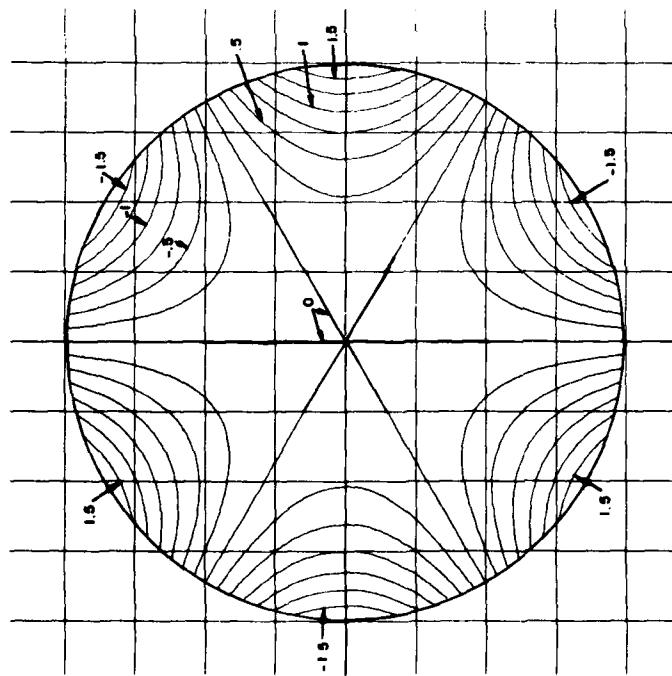


INTENSITY

CONA

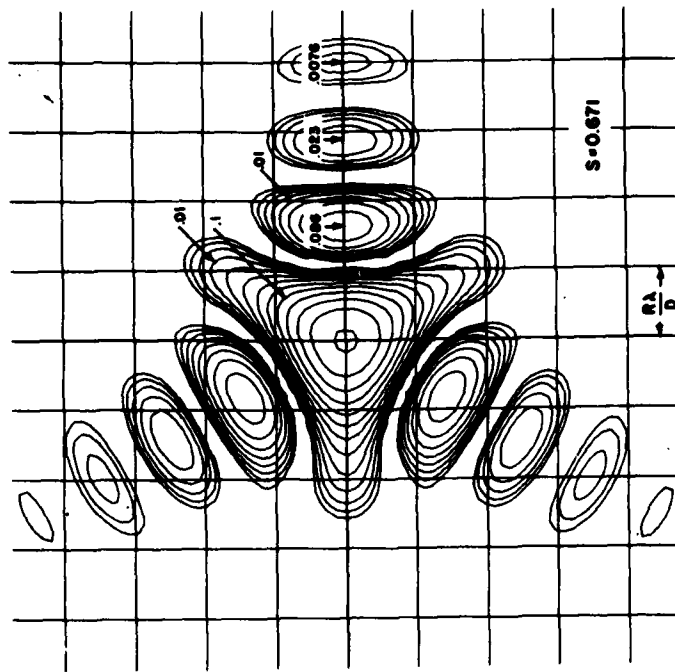
$S=0.651$

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PHASE

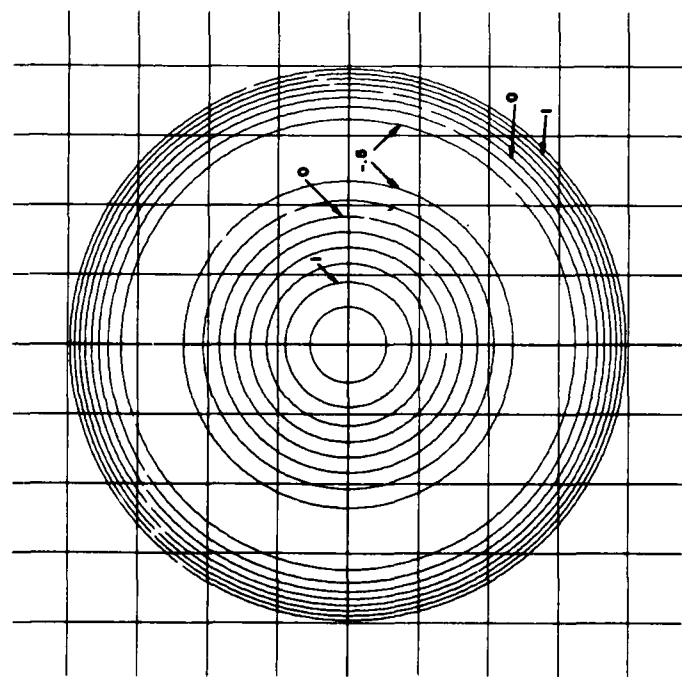
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INTENSITY

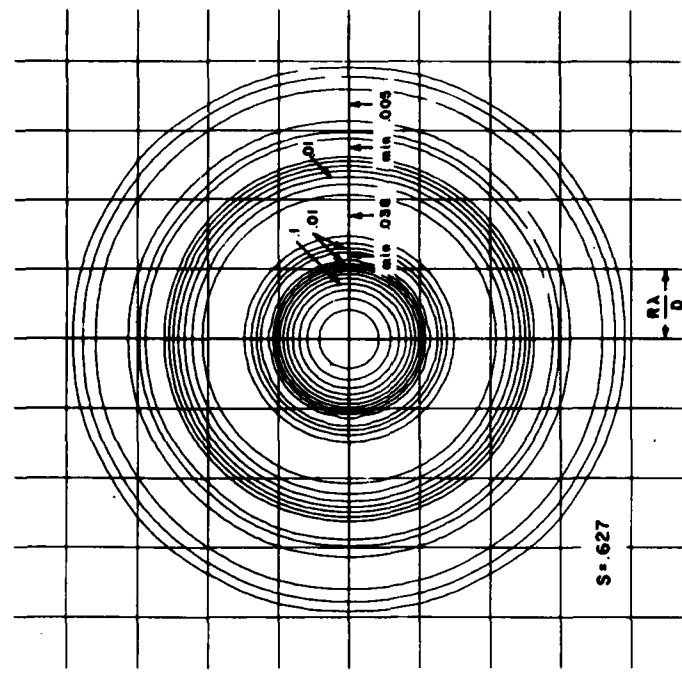
CLOVER
(SIXTH ORDER)

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PHASE

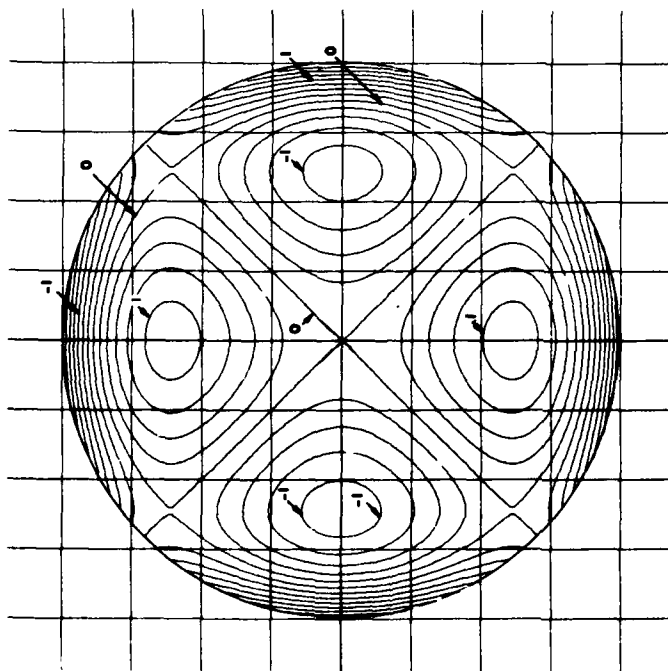
$k=11, n=4, m=0$



INTENSITY

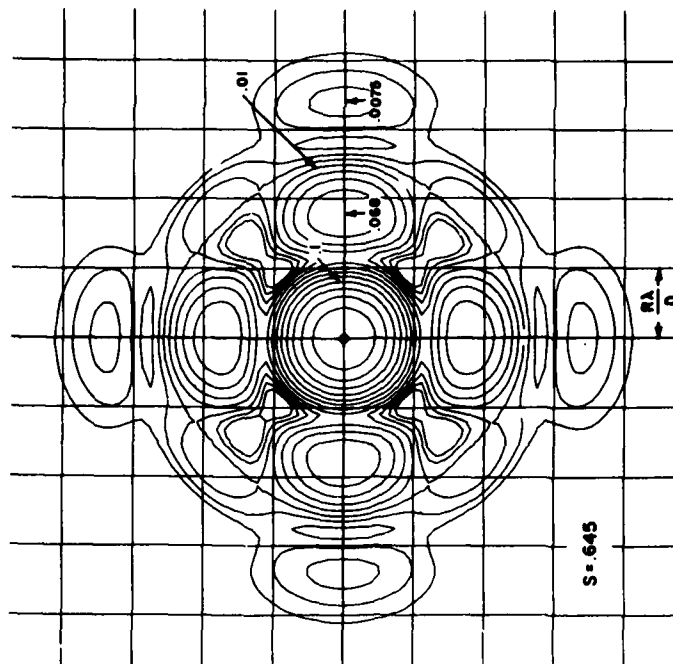
SPHERICAL ABERRATION

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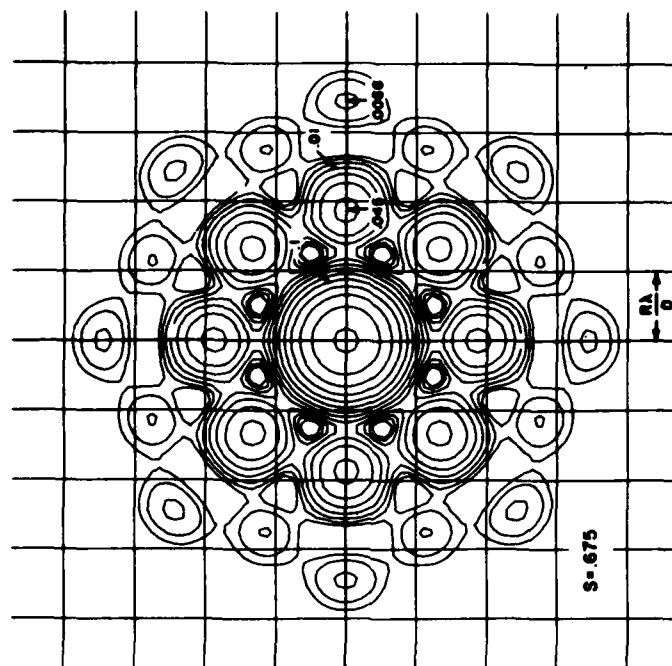
PHASE

$k = 12, n = 4, m = 2$



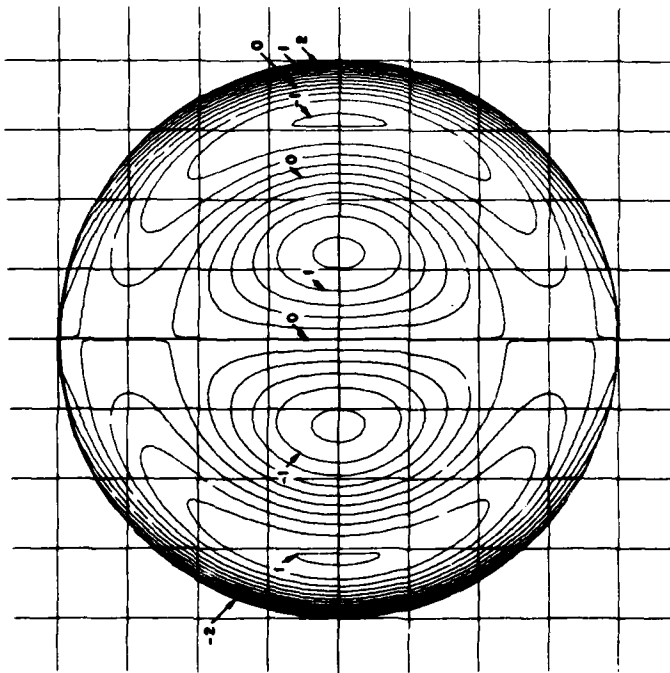
INTENSITY
ASTIGMATISM
(SIXTH ORDER)

$S = 645$

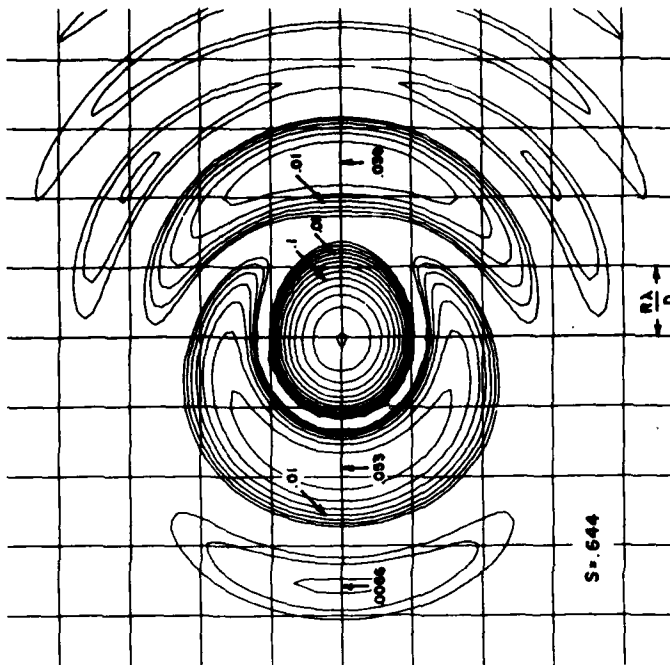
$$k=14, n=4, m=4$$


INTENSITY
LUCKY CLOVER
(EIGHTH ORDER)

TN 1980-42



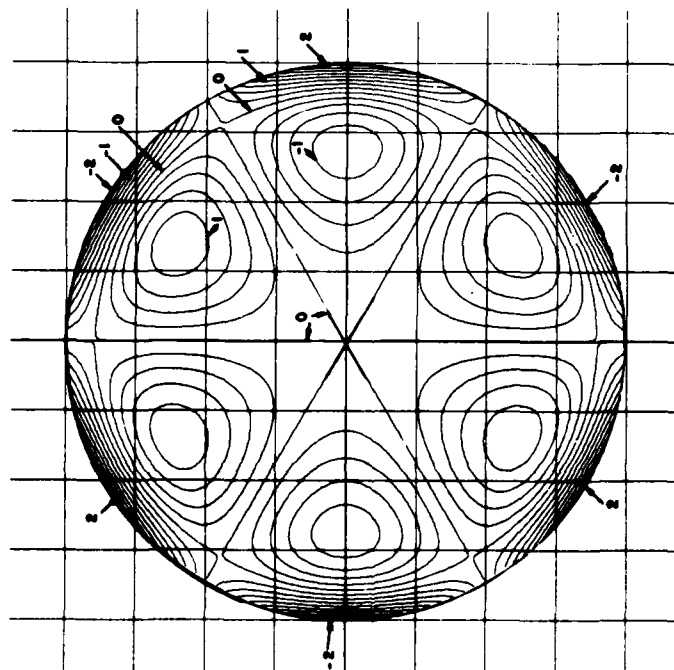
PHASE

 $k=16, n=5, m=1$ 

INTENSITY

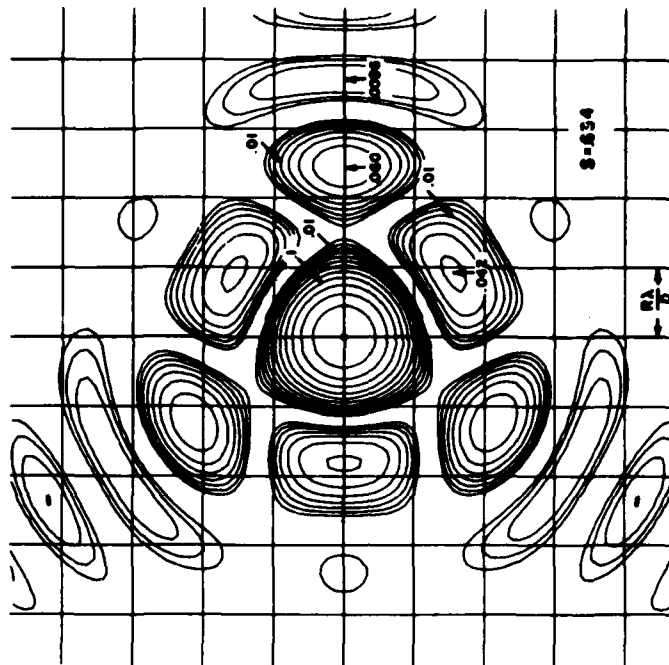
**COMA
(SIXTH ORDER)**

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PHASE

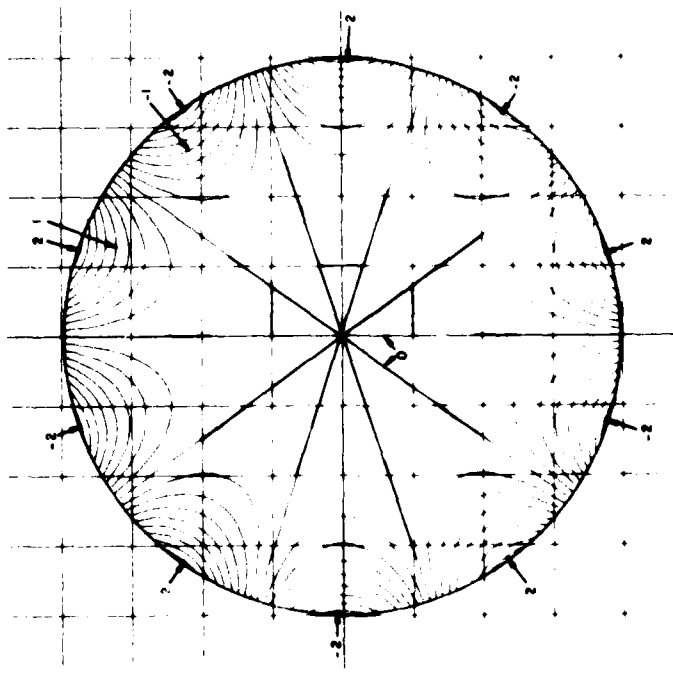
$k=18, n=5, m=3$



INTENSITY

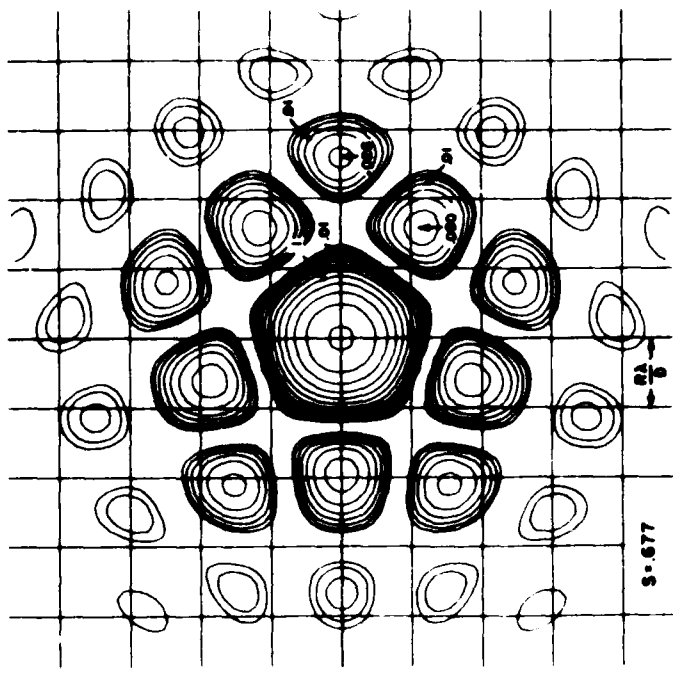
CLOVER
(EIGHTH ORDER)

TN 1980-42



PHASE

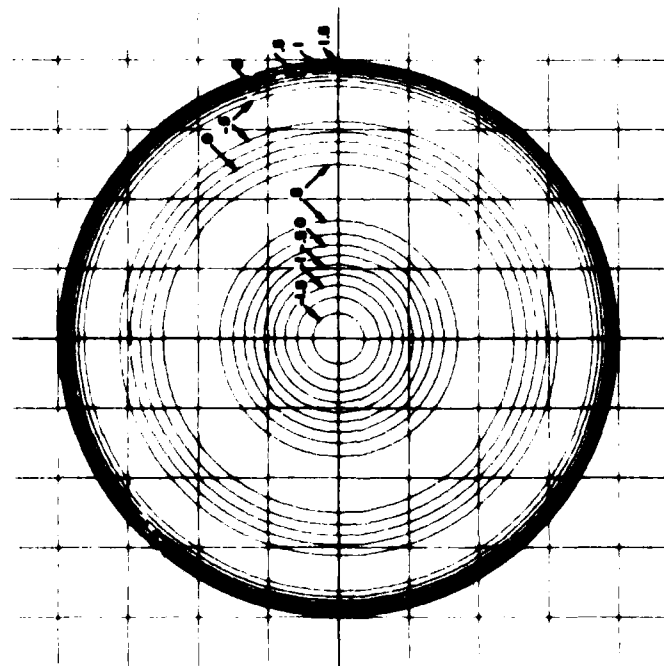
$k = 20, n = 5, m = 5$



INTENSITY

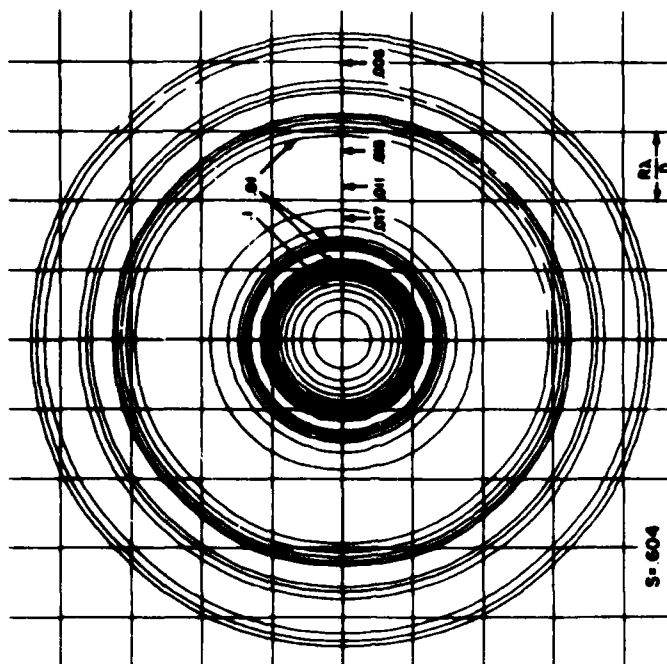
ROSETTE
(TENTH ORDER)

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PHASE

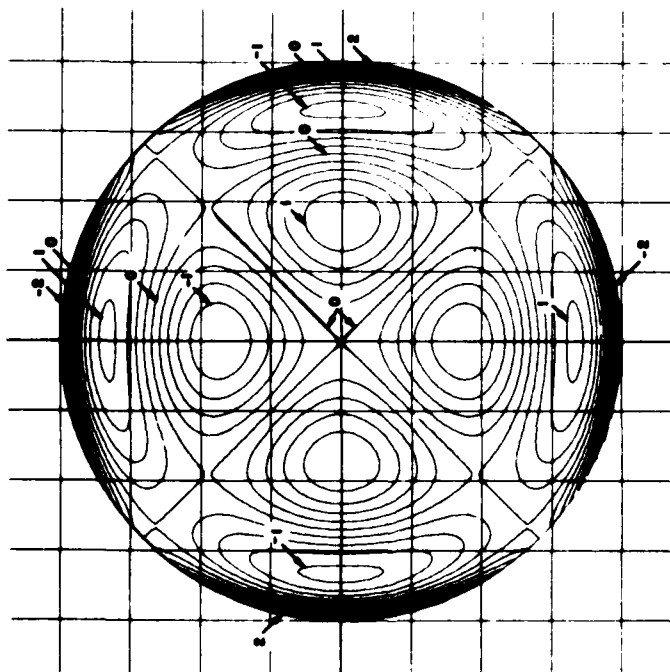
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INTENSITY

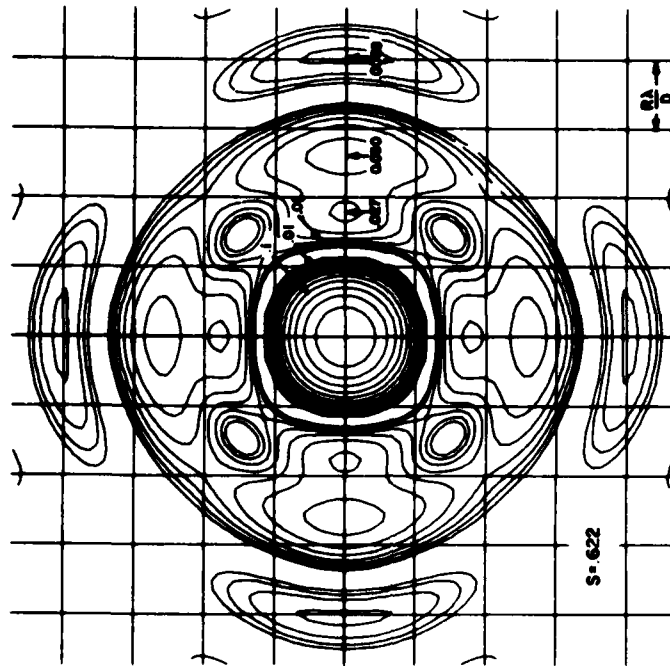
SPHERICAL ABERRATION
(SIXTH ORDER)

TM 1980-42



PHASE

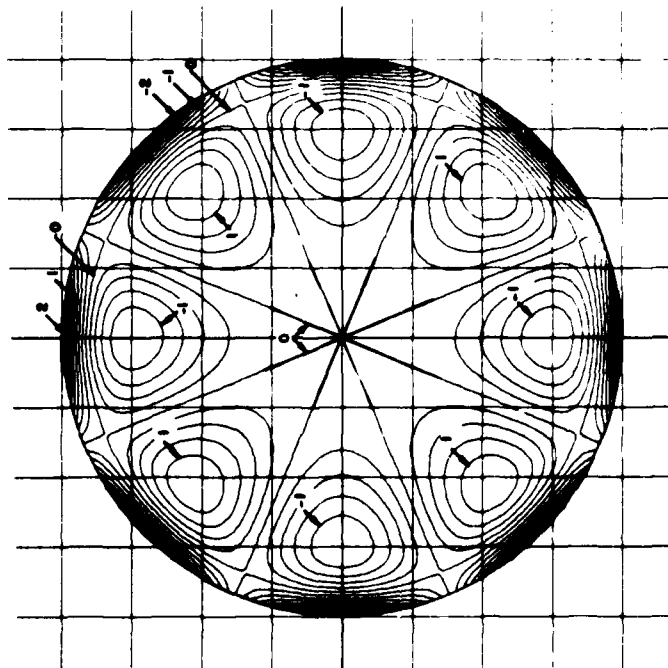
$k = 23, n = 6, m = 2$



INTENSITY
ASTIGMATISM
(EIGHTH ORDER)

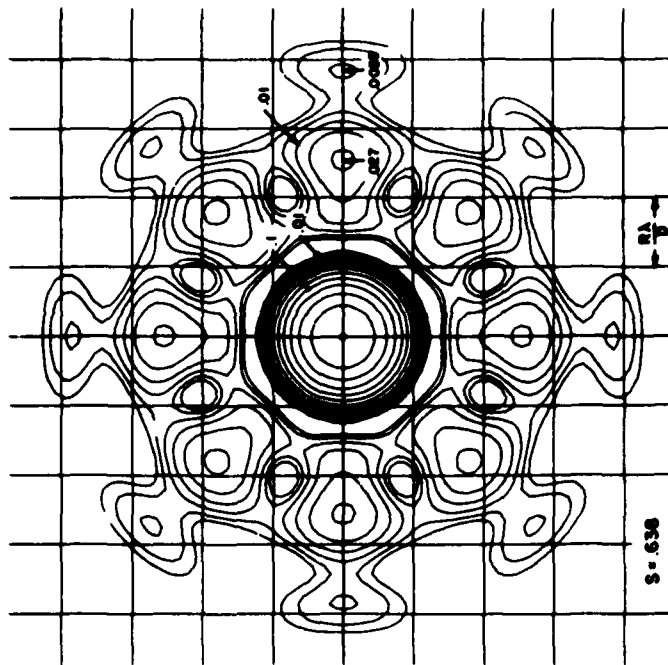
$S = 622$

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PHASE

$k = 25, n = 6, m = 4$



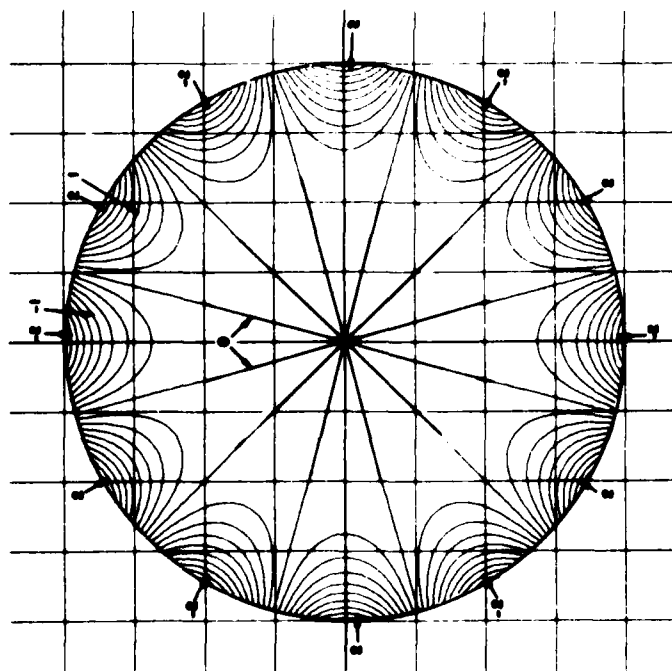
INTENSITY

LUCKY CLOVER
(TENTH ORDER)

$S = 636$

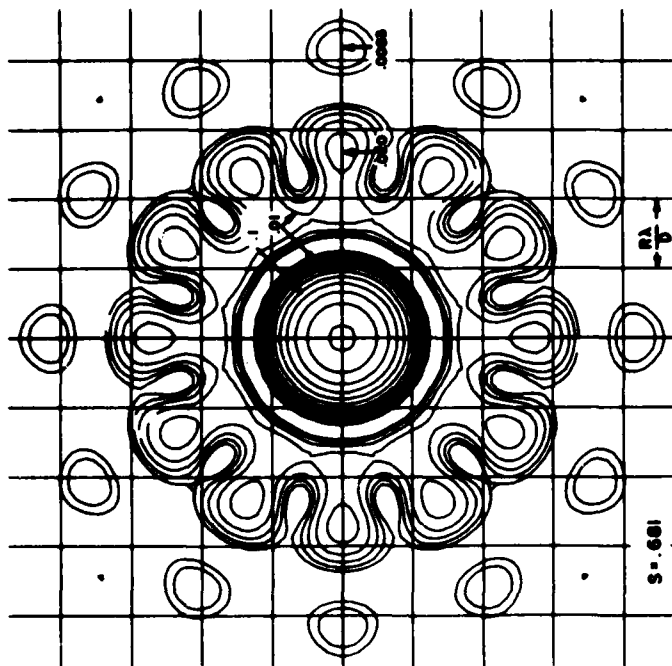
$\frac{R_1}{R_0}$

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PHASE

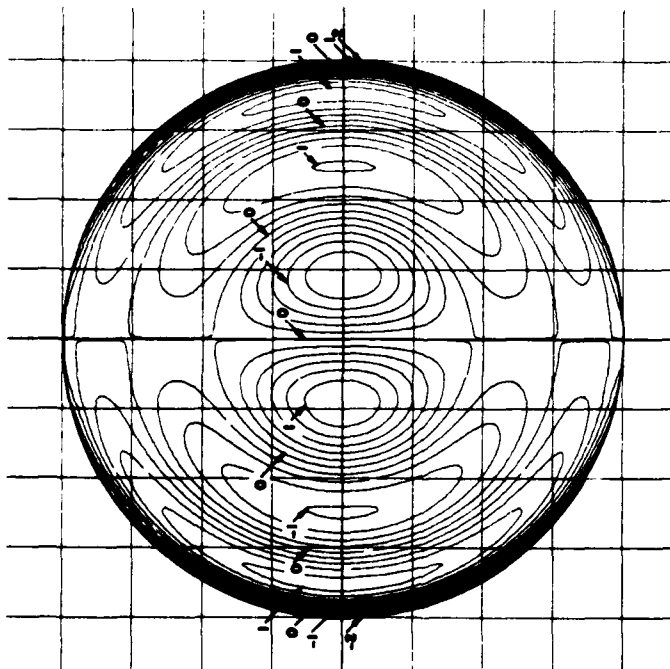
$k=27, n=6, m=6$



INTENSITY

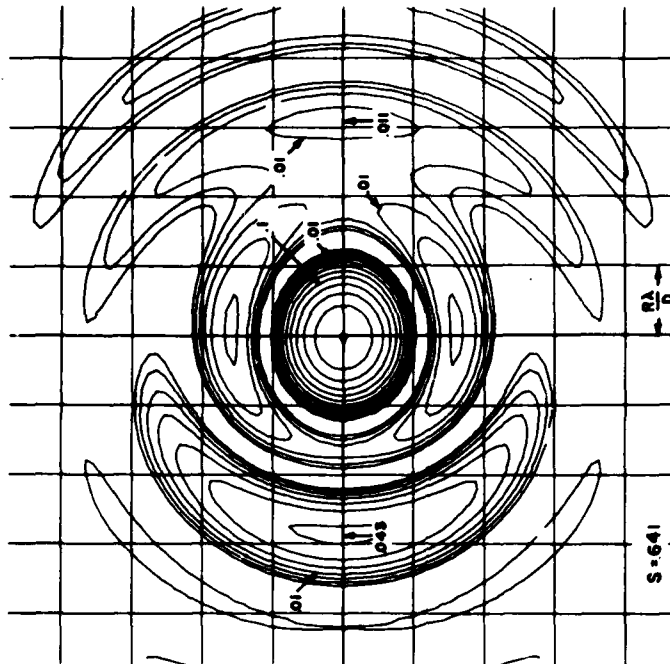
LILY
(TWELFTH ORDER)

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PHASE

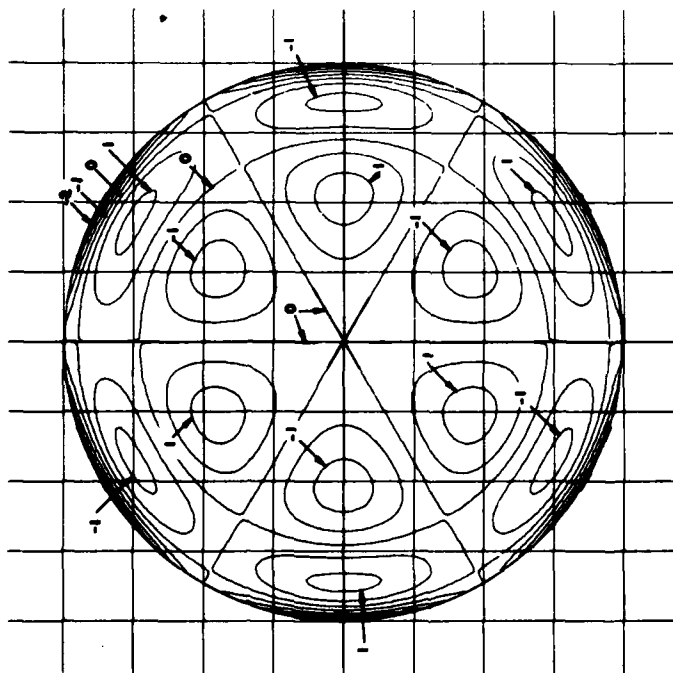
$k = 29, n = 7, m = 1$



INTENSITY

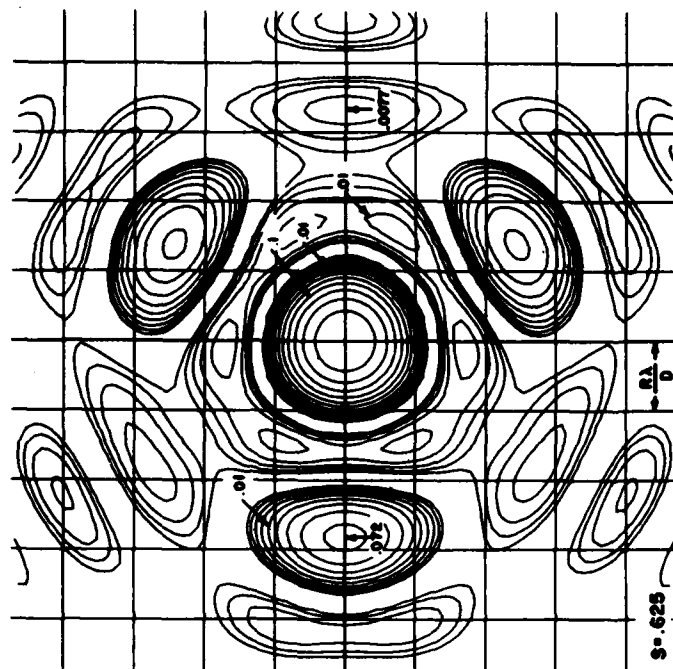
COMA
(EIGHTH ORDER)

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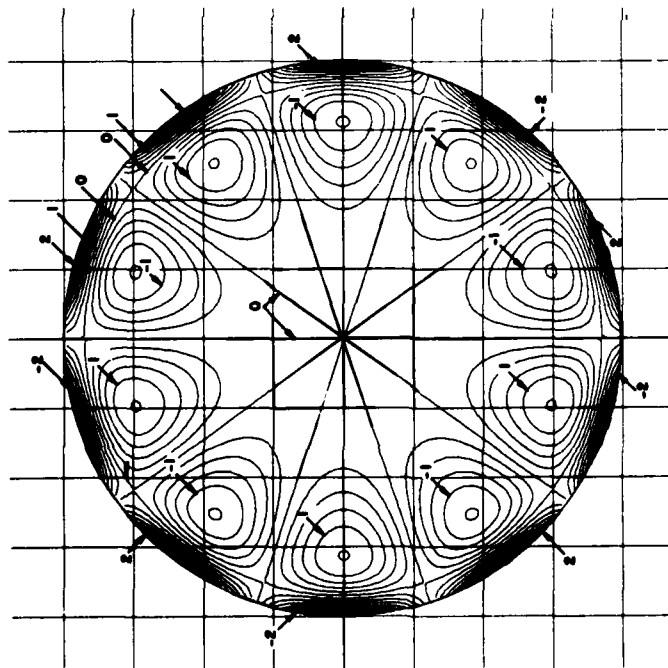
PHASE

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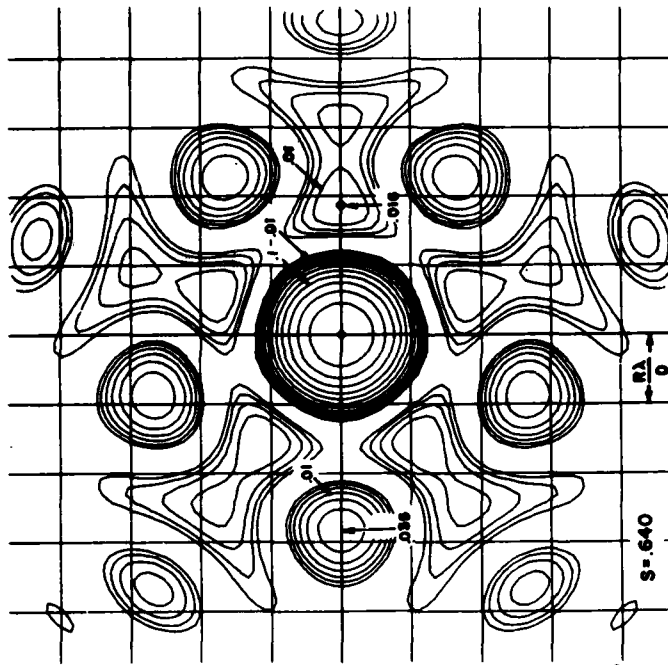
INTENSITY
CLOVER
(TENTH ORDER)

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PHASE

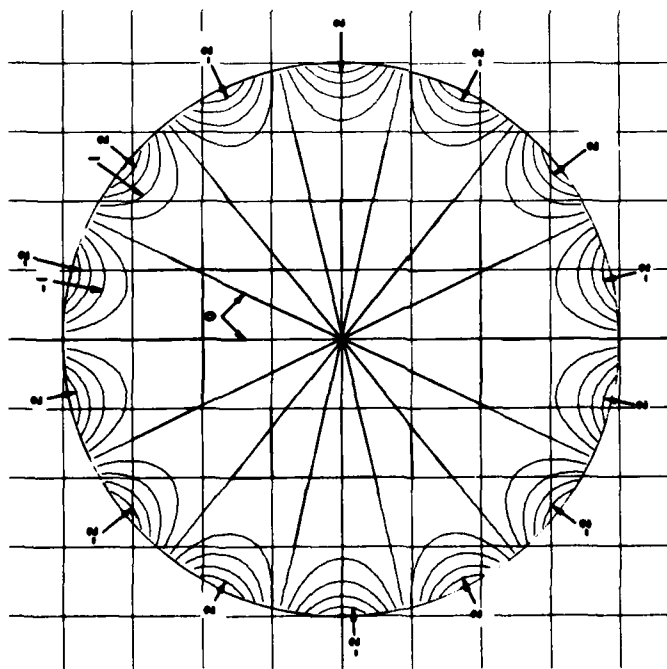
$k = 33, n = 7, m = 5$



INTENSITY

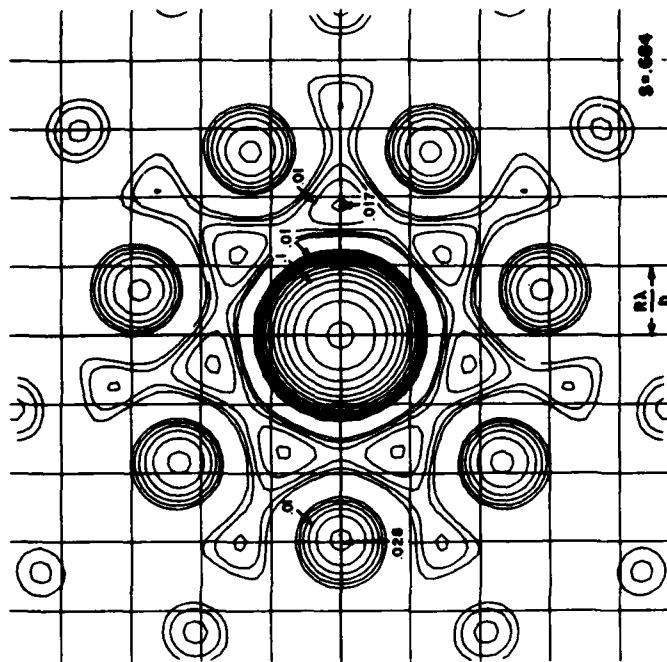
ROSETTE
(TWELFTH ORDER)

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PHASE

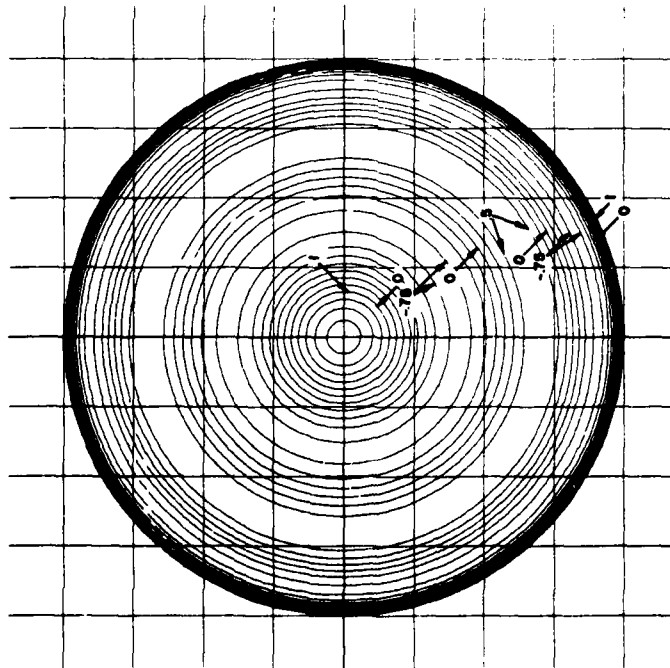
$k=35, n=7, m=7$



INTENSITY

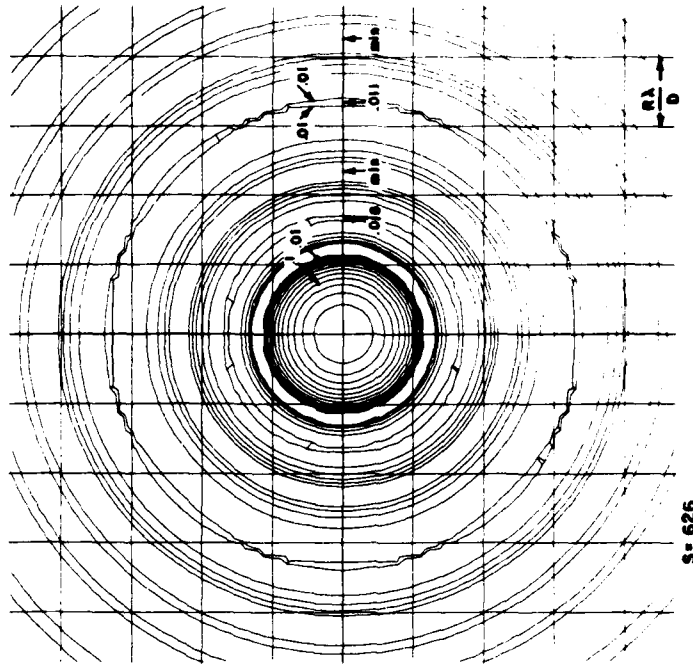
SEVEN LEAF
(FOURTEENTH ORDER)

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PHASE

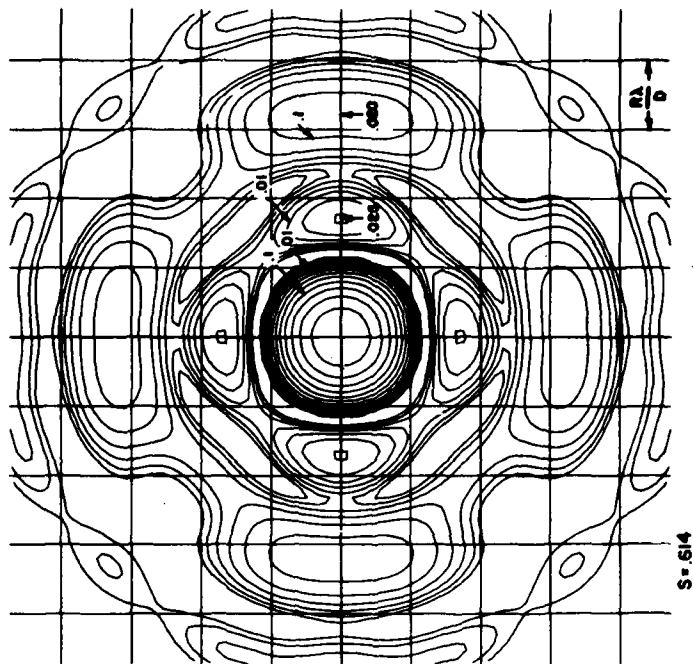
$k = 3/2, n = 8, m = 0$



INTENSITY

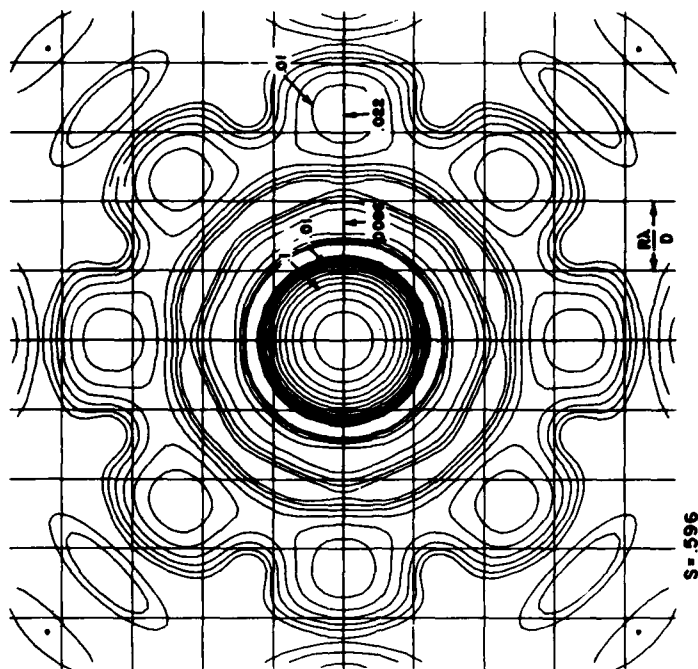
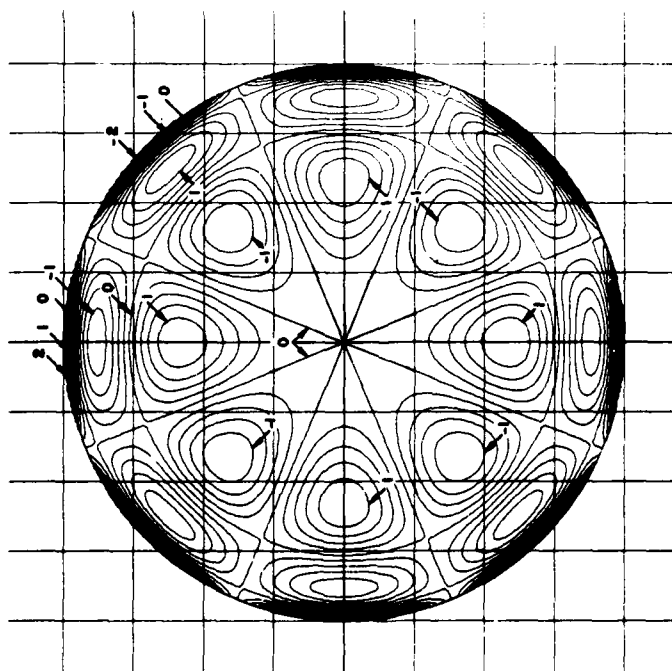
SPHERICAL ABERRATION
(EIGHTH ORDER)

S = 626

$k=38, n=8, m=2$ 

INTENSITY
ASTIGMATISM
(TENTH ORDER)

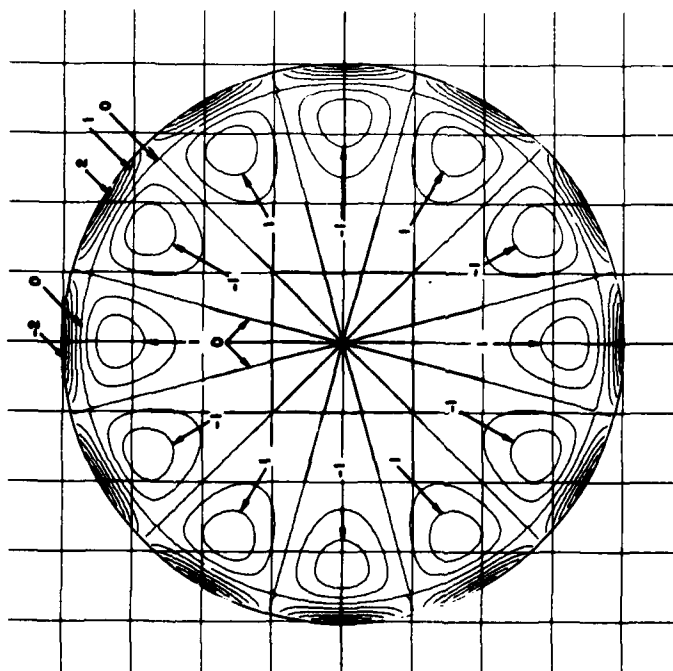
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INTENSITY
LUCKY CLOVER
(TWELFTH ORDER)

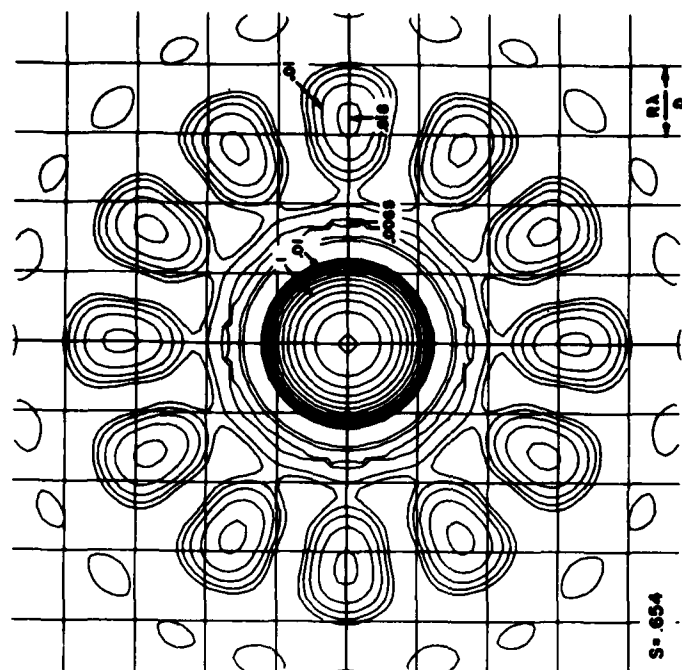
PHASE
 $k=40, n=8, m=4$

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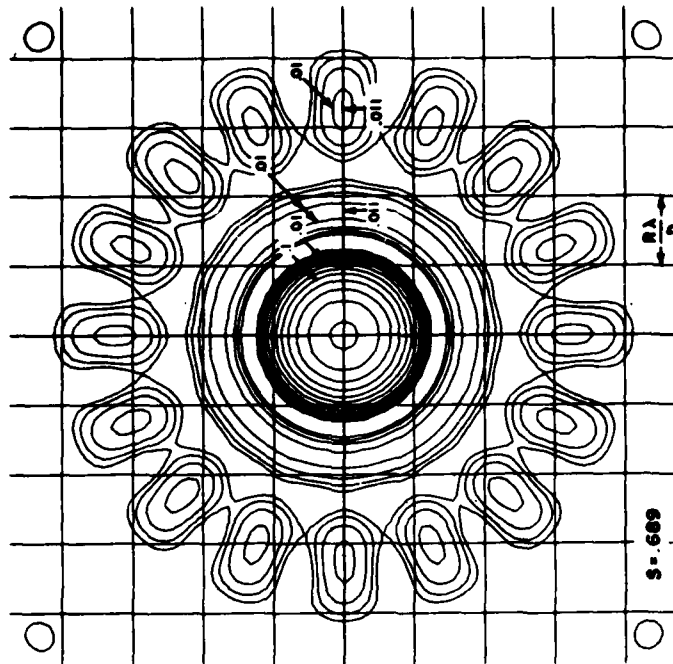
PHASE

$k = 42, n = 8, m = 6$



INTENSITY

LILY
(FOURTEENTH ORDER)

$k=44, n=8, m=3$ 

**SPIDER
(SIXTEENTH ORDER)**

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) We present in this report the phase of a wave front as described by the Zernike polynomials and the corresponding intensities in the focal plane.		

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