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Test Certificate

1,88m Primary Mirror M₁

Kottamia

Oberkochen
10th October 1996

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1. Requirements and results

The requirement concerning the Kottamia primary was defined as follows:

The encircled energy concentration of the wavefront has to be less than 0.3 arcsec for an amount of 80%.

$$E_{80\%} < 0.3 \text{ arcsec dia}$$

During final testing of the Kottamia primary the following results have been obtained:

encircled energy concentration :

$$E_{80\%} = 0.24 \text{ arcsec dia}$$

focal length : $f = 9138.4 \text{ mm} \pm 1\text{mm}$

2. Blank acceptance at Schott

The acceptance of the 1,88m Primary blank took place at the 24th of July 1995 in Mainz at the Schott plant. The pictures show the happy customers and the people from Schott and ZEISS.

The high ZERODUR quality is listed in the Schott documents which are included in the blank certificate OT -0795473 from Schott .

(added in Appendix -8-)

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Blank acceptance at Schott in Mainz July 24th 1996

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from left to right:

*Köhler, Heilemann, Dr. Anas Osman, Prof. Hassan Sobhy,
Prof. Hanafi Deebes, Knapp, Ibrahim Ghafar, Kuohl*



from left to right:

*Köhler, Heilemann, Dr. Anas Osman, Prof. Hassan Sobhy,
Prof. Hanafi Deebes, Knapp, Ibrahim Ghafar*

In front of the ZERODUR-blank



From left to right:

Dr. Anas Osman, Prof. Hanafi Deebes, Knapp, Prof. Hassan Sobhy, Köhler



From left to right:

Muhammad Ibrahim Ghafar, Dr. Anas Osman, Prof. Hanafi Deebes, Knapp, Prof. Hassan Sobhy, Köhler

3. Test philosophy

In order to control the polishing process and in order to verify the optical quality of the KOTTAMIA primary we applied interferometry. As the result we obtained the wavefront error due to the mirror shape.

The calculation of the encircled energy has been based on the measured wavefront. If we have a very high accuracy during interferometry, the calculation of the encircled energy is very precise too.

In order to evaluate the focal length we measured the E-value. (The E-value is the distance between the vertex of the primary and the vertex of the null corrector lens).

4. Interferometrical testing

Optical setup

For interferometrical testing of the KOTTAMIA primary a vibration isolated optical table was situated close to the center of curvature at a height of about 15m above the mirror. At the table the complete interferometrical setup of Twyman-Green type was erected and adjusted. As the light source a HeNe-type laser was applied. The measuring wavelength was 633 nm. The used CCD-camera was connected to the host computer, where phase evaluation was performed.

For alignment of the interferometrical setup with respect to the mirror the optical table and one folding mirror was adjustable.

Null Corrector

Because the primary under test is the autocollimation mirror and the shape of the primary is of aspherical (parabolic) type, a Null corrector (designed for the Kottamia primary) producing the parabolic wavefront was used for interferometrical testing.

Phase evaluation

For phase evaluation we applied our DIRECT 100 (interferometer) software. The DIRECT 100 evaluates the phase map in video real time (25 times per second). For each phase calculation only one frame (interferogram) has to be taken. In combination with the very short exposure time DIRECT100 is very insensitive to vibration. On the other hand it allows to average a large number of interferograms with a rate of 25 per second in order to reduce effects of air turbulences as well as residual mathematical errors without any artificial smoothing of the wavefront. Applying the test we got very long light pathes, so single frame evaluation (with the short exposure time) and real time averaging was very helpful to obtain the results with the required accuracy.

Test procedure

In order to separate the mirror inherent residual errors from non-rotationally symmetric errors of the test setup (including test tower), the mirror was measured in 6 different rotational positions relative to the interferometrical setup. The phase maps have been rotated back to the original position of the mirror and have been averaged. This gives us the information about the mirror inherent error.

5. Testing the E-value

To fabricate the KOTTAMIA primary two points have been of highest importance. The null corrector has to produce the predicted aspherical wavefront and the correct distance between the vertex of the null corrector and the KOTTAMIA primary has to be guaranteed within a range relatively small compared to the absolute distance (E-value).

We have a fixed reference point at our vibration isolated table in the test tower where the interferometrical setup was located. Using this reference point for situating a theodolit we

measured the angle between two opposite points at the mirrors shape with an accuracy of better than 1arcsec.

Additionally we measured the distance between these two points with an accuracy of better than 0.2 mm and calculated the height over vertex using the parabolic equation.

If we know all these values we determined the E-value with an accuracy of better than 2mm.

6. Optical parameter calculation

Based upon the measured E-Value and on the measured wavefront we determined the optical parameters of the KOTTAMIA primary.

Multiplying the measured wavefront by a factor of 0.5 we obtained the surface error.

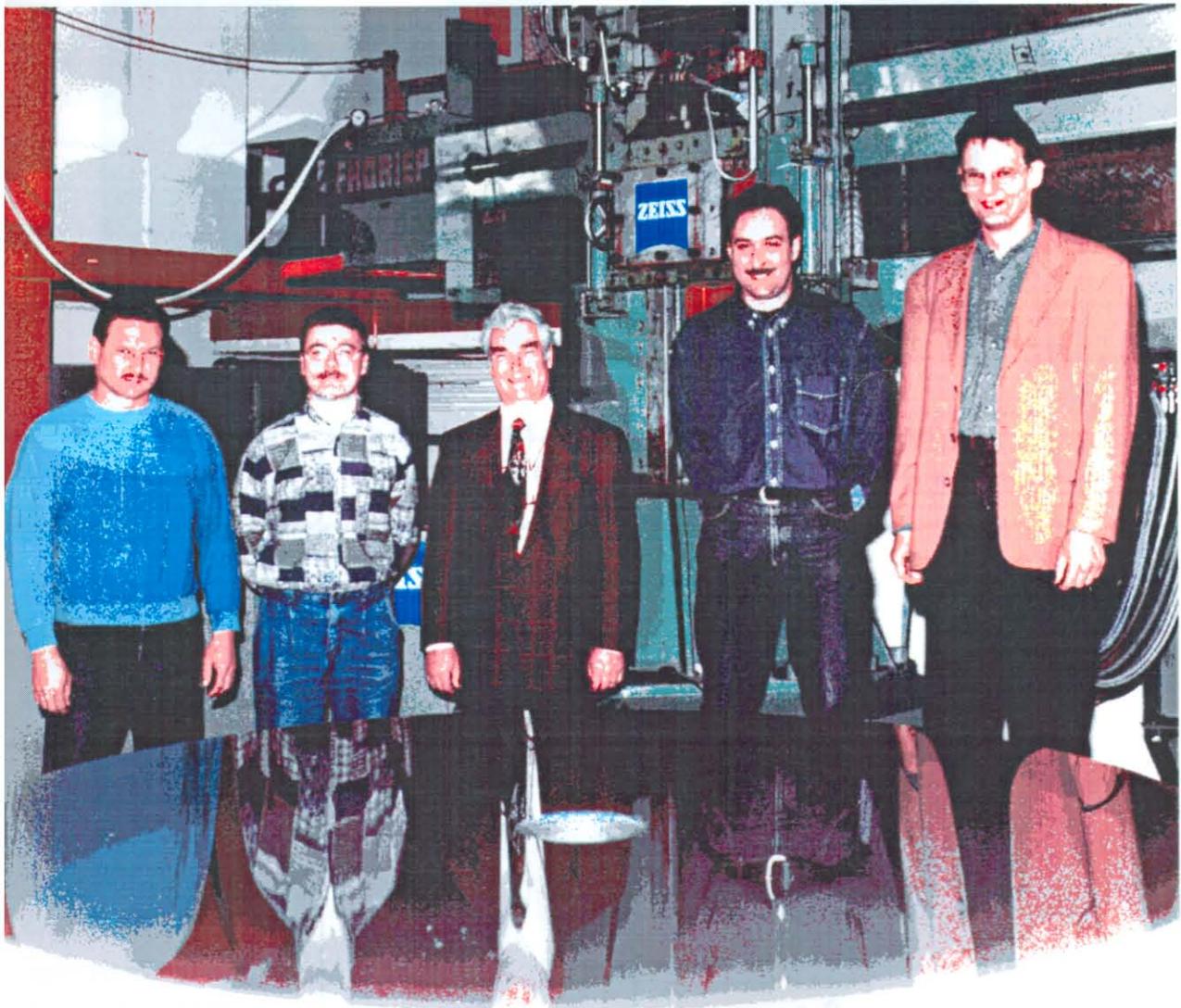
In appendix 1 the results concerning the surface error of the KOTTAMIA primary after the last fabrication step are attached.

The **encircled energy** concentration of the KOTTAMIA primary was calculated based upon the measured wavefront. A lateral resolution of 34 points over the diameter was applied for this calculation. The detailed result is shown in appendix 2.

The **focal length** of the primary was calculated using the measured E-value and using the mathematical model of the test setup. It is more described in appendix 3.

If the correct design and assembly of the **null corrector** is indispensable for a correct mirror fabrication, the complete verification of the null corrector is documented in appendix 4.

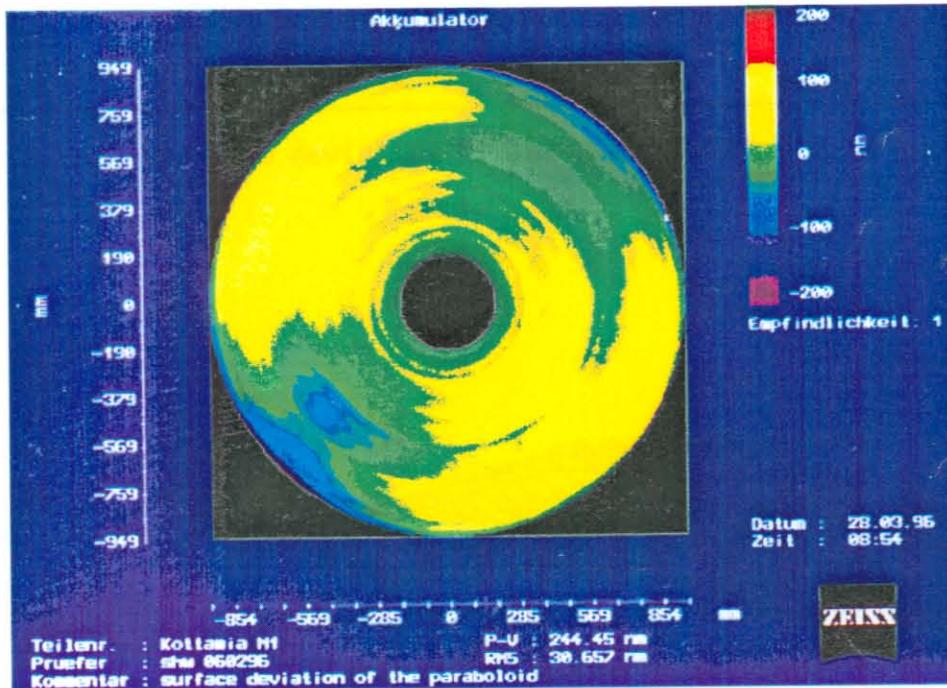
Although it is not of interest for the final state of the KOTTAMIA primary, the surface topography, the encircled energy concentration and the radius of curvature of the sphere - before starting of aspherisation - was documented in appendix 5,6,7.

7. Project-team at ZEISS in Oberkochen

from left to right:

Erdmann, Schillke, Knoch, Schwarz, Dr. Böttner

surface topography of the KOTTAMIA primary



Zernike - coefficients

after removing of constant, tilt, focus and coma

Aberration	X-coefficient [nm]	Y-coefficient [nm]
constant	---	---
tilt	---	---
focus	---	---
astigmatism	13	-56
coma	---	---
spherical aberr. h^4	- 7	
triangular coma	- 7	14
astigmatism h^4	- 2	3
coma h^5	11	- 1
spherical aberr. h^6	-20	
4-wave error	24	- 6

P-V : 244 nm; RMS : 30.7nm surface

surface topography of the KOTTAMIA primary

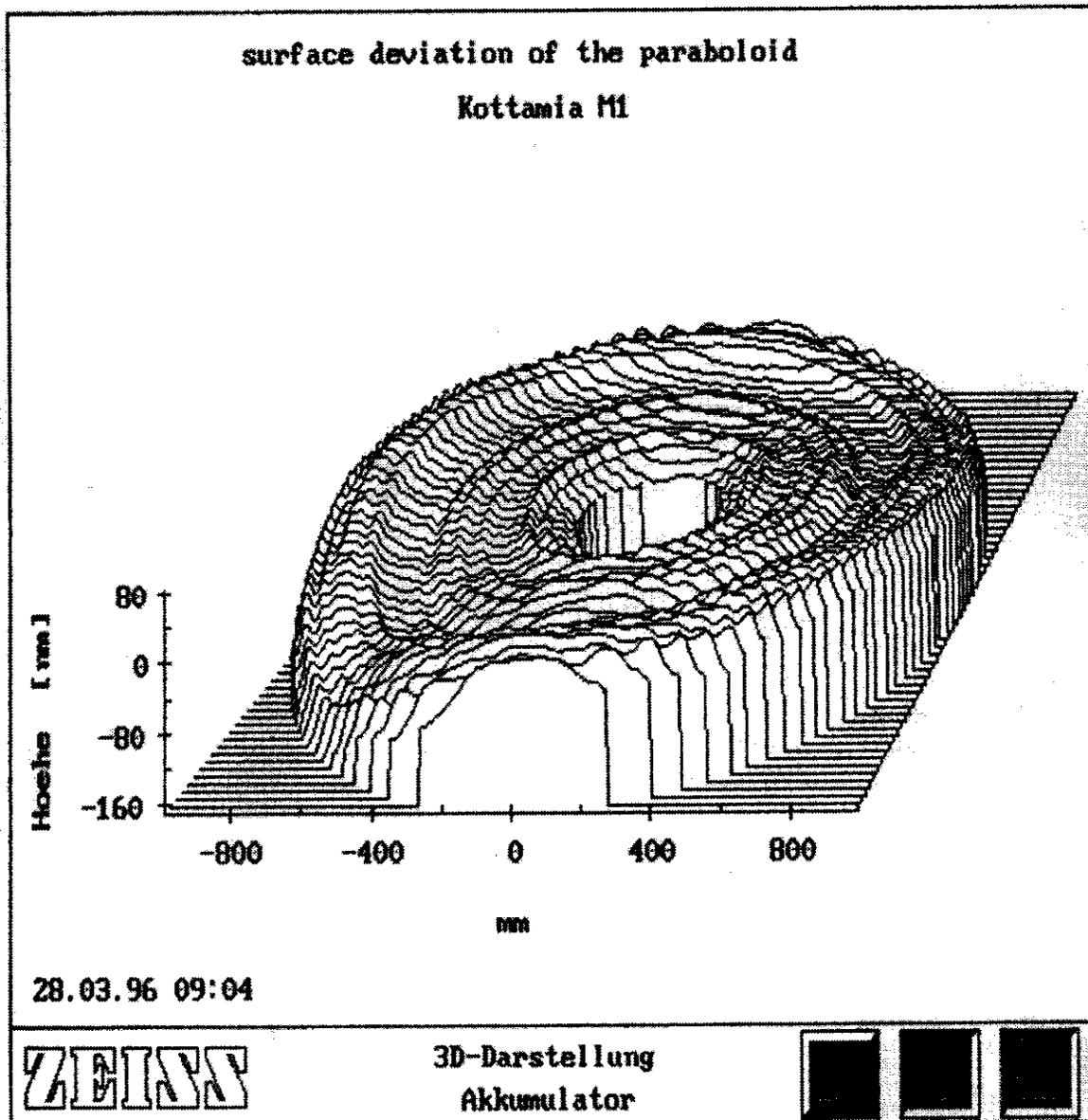


Table with Zernike-coefficients for 6 rotated positions**KOTTAMIA M1 surface**

maps are rotated back to 0° orientation

Drehstellung	A.stigm. [nm]	[°]	sph.A. h ² 4 [nm]	sph.A. h ⁴ 8 [nm]	sph.A. h ⁶ 8 [nm]	sph.A. h ⁸ 10 [nm]	sph.A. h ¹⁰ 10 [nm]	sph.A. h ¹² 12 [nm]
0°	61	130	-20	-8	-41	-4	-5	-5
60°	92	150	-30	-3	-37	-8	-3	-3
120°	29	142	-21	-6	-38	5	1	1
180°	84	127	-10	-15	-34	0	6	6
240°	102	148	-18	-6	-43	8	3	3
300°	22	21	-3	-14	-38	5	1	1



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appendix 1/4¹³
appendix 1/4

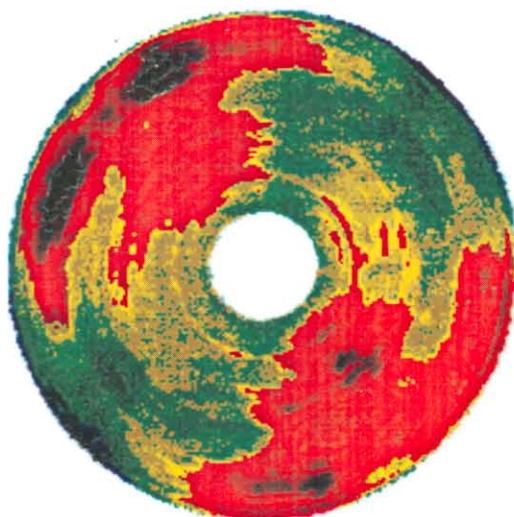
0° contour plot + Zernike coefficients

Teilnr. : Kottamia M1
Pruefer : slk 060296
Kommentar : 0 grad Stellung

Aberration	Betrag [nm]	Winkel [Grad]
Konstante	-2.968	
Kippung	0.034	229.455
Defokussierung	4.549	
Astigmatismus	61.430	129.751
Koma	0.268	333.412
Sph.Aberriation	-19.757	
Sph.Aberriation r^6	-7.798	
Sph.Aberriation r^8	-40.725	
Sph.Aberriation r^10	4.375	
Sph.Aberriation r^12	4.934	

Gealtige Bildpunkte: P-V : [nm]	MDE : [nm]	RMS : [nm]
113136	263.910	35.202

Zernike-Koeffizienten



-201.931 -39.966 81.589
 Teilnr. : Kottamia M1
 Pruefer : slk 060296
 Kommentar : 0 grad Stellung
 Messdatum : 24.02.96 09:58

P-V : 263.910 nm
 RMS : 35.202 nm
 Aenderung : 22.12.96 10:01

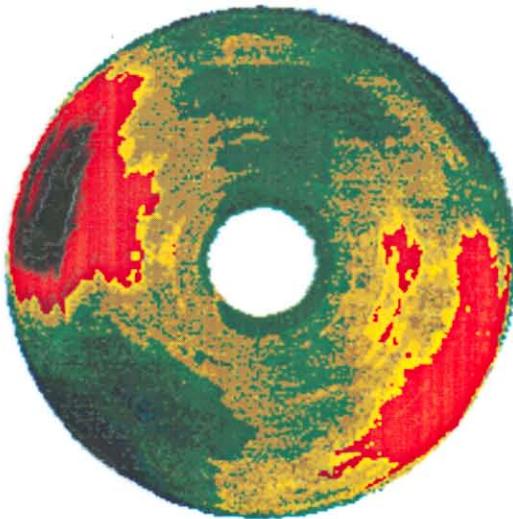
60° contour plot + Zernike coefficients

Teillenz. : Kottamia M1
 Pruefer : slk 060296
 Komzentar : 60 grd Stellung

Aberration	Betrag [nm]	Winkel [Grad]
Konstante	-2.315	
Kippung	0.192	275.462
Defokussierung	6.333	
Astigmatismus	51.903	150.745
Koma	0.743	100.824
Sph.Aberration	-10.164	
Sph.Aberration z ⁶	-2.501	
Sph.Aberration z ⁸	-17.353	
Sph.Aberration z ¹⁰	3.284	
Sph.Aberration z ¹²	2.606	

Gesamte Bildpunkte: P-V : [nm] MTM : [nm] RMS : [nm]
 119224 357.163 -235.975 47.175

Zernike-Koeffizienten



-235.975 -57.393 131.163

Teillenz. : Kottamia M1
 Pruefer : slk 060296
 Komzentar : 60 grd Stellung
 Messdatum : 04.02.96 10:14

P-V : 357.163 nm
 RMS : 47.175 nm

Änderung : 02.12.96 10:01

120° contour plot + Zernike coefficients

Teilleit. : Kottamia M1
 Pruefer : slk 060296
 Kommentar : 120 grad Stellung

Aberration	Betrag [nm]	Winkel [Grad]
Konstante	-1.807	
Kippung	1.211	297.450
Defokussierung	4.727	
Astigmatismus	28.123	182.049
Koma	0.377	90.266
Sph. Aberration	20.301	
Sph. Aberration r ⁶	-5.359	
Sph. Aberration r ⁸	-22.251	
Sph. Aberration r ¹⁰	4.714	
Sph. Aberration r ¹²	1.411	

Geltige Bildpunkte: P-V : [nm] MIN : [nm] RMS : [nm]
 119351 261.307 -172.992 26.973

Zernike-Koeffizienten:



-172.992 -42.319 88.315
 Teilleit. : Kottamia M1
 Pruefer : slk 060296
 Kommentar : 120 grad Stellung
 Messdatum : 04.07.96 10:56

P-V : 261.307 nm
 RMS : 26.973 nm
 Rendering : 02.12.96 10:01

180° contour plot + Zernike coefficients

Teilenr. : Kottamia M1
 Pruefer : slk 160296
 Kommentar : 180 grad Stellung

Aberration	Betrag [nm]	Winkel [Grad]
Konstante	-1.156	
Kippung	0.662	12.490
Defokussierung	2.048	
Astigmatismus	54.564	108.658
Koma	1.810	178.962
Sph.Aberriation	-9.863	
Sph.Aberriation r ⁶	-15.071	
Sph.Aberriation r ⁸	-13.705	
Sph.Aberriation r ¹⁰	0.001	
Sph.Aberriation r ¹²	3.599	

Stetige Bildpunkte: P-V : [nm] MIE : [nm] RMS : [nm]
 119566 167.575 -250.917 48.838

Zernike-Koeffizienten



-250.917 -67.130 116.657

Teilenr. : Kottamia M1
 Pruefer : slk 010296
 Kommentar : 180 grad Stellung
 Messdatum : 04.02.96 11:17

P-V : 167.575 nm
 RMS : 48.838 nm

Wendung : 02.12.96 10:04

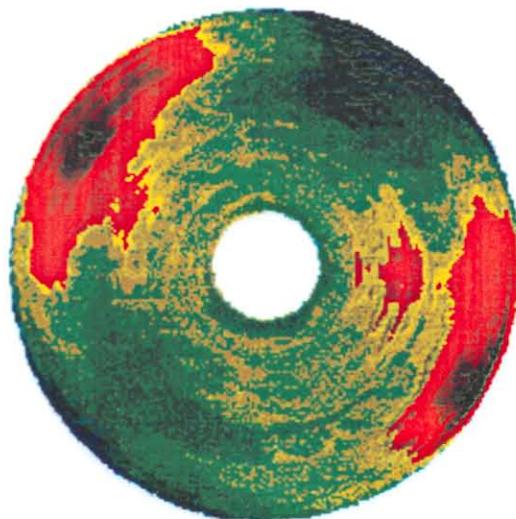
240° contour plot + Zernike coefficients

Teilleit. : Kottamia M1
 Pruefer : shv 161296
 Kommentar : 240 grad-Stellung

Aberration	Betrag [nm]	Winkel [Grad]
Konstante	-1.986	
Kippung	1.054	40.712
Defokussierung	5.250	
Astigmatismus	102.325	148.423
Koma	0.854	138.051
Sph. Aberration	-18.234	
Sph. Aberration r^4	-5.531	
Sph. Aberration r^6	-42.735	
Sph. Aberration r^{10}	8.717	
Sph. Aberration r^{12}	2.673	

Geltige Bildpunkte: P-V : [nm] MIN : [nm] RMS : [nm]
 119314 357.024 -277.588 48.924

Zernike-Koeffizienten:



-229.588 -49.076 123.436
 Teilleit. : Kottamia M1
 Pruefer : shv 161296
 Kommentar : 240 grad-Stellung
 Messdatum : 04.02.96 11:53

P-V : 357.024 nm
 RMS : 48.924 nm
 Aenderung : 02.12.96 09:57

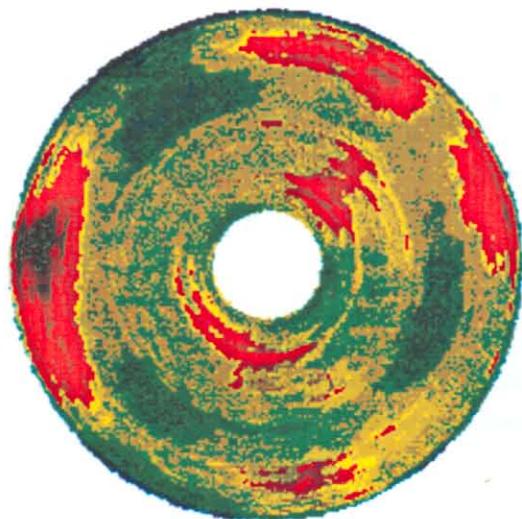
300° contour plot + Zernike coefficients

Teilenr. : Kottamia M1
Pruefer : shw 161296
Kommentar : 300 grad-Stellung

Aberration	Betrag [nm]	Winkel [Grad]
Konstante	-0.789	
Kippung	1.199	135.195
Defokussierung	2.213	
Astigmatismus	21.661	21.658
Koma	1.191	282.096
Sph.Aberration	-2.635	
Sph.Aberration r^6	-13.932	
Sph.Aberration r^8	-18.370	
Sph.Aberration r^10	4.889	
Sph.Aberration r^12	1.127	

Gueltige Bildpunkte: P-V : [nm] MIN : [nm] RMS : [nm]
119542 247.644 -163.410 26.616

Zernike-Koeffizienten



-163.410 -39.598 84.734
Teilenr. : Kottamia M1 P-V : 247.644 nm
Pruefer : shw 161296 RMS : 26.616 nm
Kommentar : 300 grad-Stellung
Messdatum : 14.02.96 12:23 Aenderung : 02.12.96 09:58



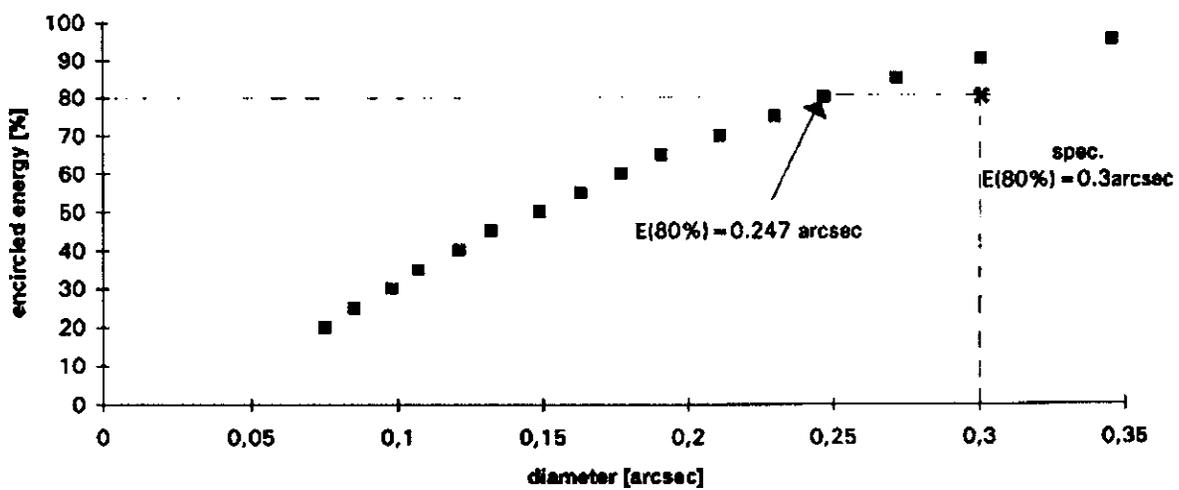
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appendix 2

Encircled energy of the Kottamia Primary



Focal length of the Kottamia Primary

Protokoll E-Wert-MessungObjekt: Kottamia M1Datum: 5.2.96 (final state)

Abstand Theodolit - K-System:

$$x = 856,05 \text{ mm}$$

Abstand Theodolit - Sehne über Basis D:

$$H = \frac{D}{2} \cdot \frac{1}{\tan\left(\frac{\theta}{2}\right)}$$

mit
Winkelmessung: $\theta = 6^\circ 12' 43''$ Basis über Spiegel: $D = 1920,85 \text{ mm}$

$$H = 17699,57 \text{ mm}$$

Höhe über Spiegelscheitel bis zur Sehne:

$$\text{sag} = \frac{D^2}{8 \cdot R^2} \quad \text{mit } R^2 = 18300 \text{ mm}$$

$$\text{sag} = 25,20 \text{ mm}$$

Dannit folgt E-Wert:

$$E = x + H + \text{sag}$$

$$= 18580,8 \text{ mm} \quad \pm 2 \text{ mm Toleranz}$$

Der Soll-E-Wert beträgt:

$$E_{\text{soll}} = 18592 \text{ mm}$$

E-Wert - Abweichung:

$$\Delta E = 18580,8 \text{ mm} - 18592 \text{ mm}$$

$$= -11,2 \text{ mm} \pm 2 \text{ mm}$$

Dannit ist die Brennweite:

$$f = f_{\text{soll}} + \frac{\Delta E}{2} = 9144 \text{ mm} + \frac{-11,2 \text{ mm} \pm 2 \text{ mm}}{2}$$

$$= 9138 \text{ mm} \pm 1 \text{ mm}$$

appendix 4/1Verification of the null corrector design and assembly

in order to guarant correct design and assembly of the null corrector the following steps have been performed:

1. Measurement of the refractive index of the glass what has been chosen for lens material
--> for measurement protocoll see page 4/2
2. Design of the null corrector (a two lens system)
3. Fabrication of the lenses
4. Measurement of the lens thickness
--> for measurement protocoll see page 4/3
5. Redesign of the null corrector taking into account the thickness of the fabricated lenses. Redesign means, that the distance between the two lenses of the null corrector changes slightly in order to produce the required parabolic wave.
6. Final assembly of the null corrector
7. Testing of the correct distance between the two lenses inside the null corrector
--> for measurement protocoll see page 4/4



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appendix 4/2

Null-lens design



2 m -Spiegelsystem KOTTAMIA,
K-System fuer S1

OBERKOCHEN: RECHNUNG VOM 27.10.95

ABT. -APS-T

DATEN: $f(1-4) = 363.2$; $s'(4) = 304.0$.
 $f(1-2) = 939.0$ $f(3-4) = 494.4$
 Eingang von Unendlich

ZEICHNUNG: 563618

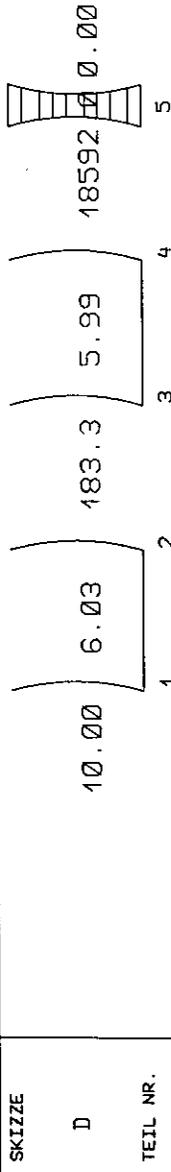
KO-APS-K02

1000

K0 HERAUSGEGEBEN AM 15.05.95

MATH -F/Hbg

RADIUS	58.294	53.860	1224.4	211.35	18288.		
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TEIL NR.							
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2H	38.0	39.3	30.4	30.3	1995.3		
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FREIER Ø	38.0	39.4	30.6	30.4	1995.0		
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Ø							
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GLASART	BK7						
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SCHMELZE	120428K27811						
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(632.8 nm)	1.51560						
------------	---------	--	--	--	--	--	--

STUFE							
-------	--	--	--	--	--	--	--

Vd	64.26						
----	-------	--	--	--	--	--	--

STUFE							
-------	--	--	--	--	--	--	--

Nur angegebene Schmelze f. BK7 120428III K27811 verwenden.
 Linsendicken wurden vermessen.
 Pruefing ist Rotationsparaboloid.

Datenblatt gilt als K1

Angegebene Radien sind IST-Radien.

TOLERANZEN: KOMBINATIONSFREIE FERTIGUNG

D		±0.05	±0.10	±0.05			
---	--	-------	-------	-------	--	--	--

KITT							
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Ø) KUEHLUNG							
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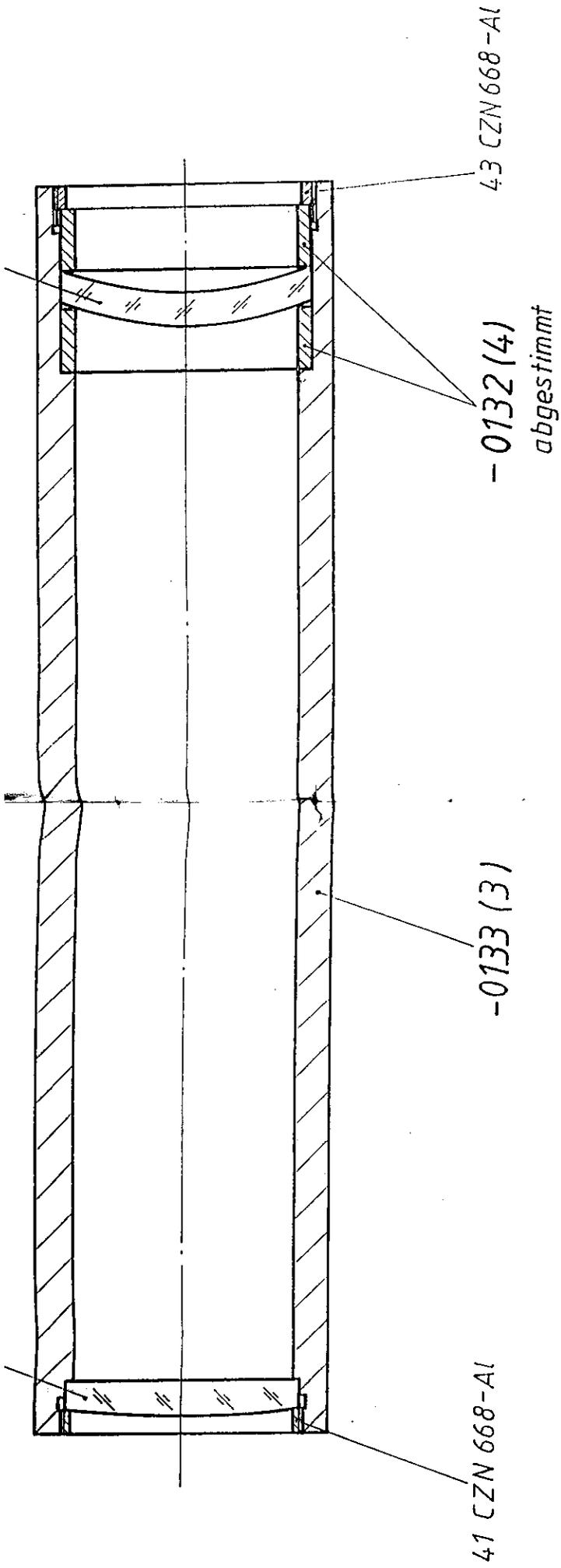
1) BLASEN		5x0.63					
-----------	--	--------	--	--	--	--	--

2) SCHLIEREN							
--------------	--	--	--	--	--	--	--

3) PASSE		0.1(0.1)	0.1(0.1)	0.1(0.1)	0.1(0.1)		
----------	--	----------	----------	----------	----------	--	--

4) ZENTR.		0.2'	0.2'	0.2'	0.2'		
-----------	--	------	------	------	------	--	--

5) UNSAUB.		0	5x0.63	5x0.63	5x0.63	5x0.63	
------------	--	---	--------	--------	--------	--------	--



19.05.95

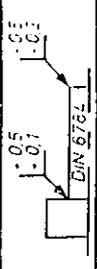
Kö

Klassifizierungsschlüssel

Maßstab 1:1

K-System

Geprüft auf Gerätesicherheit:
Sicherheitsstufe: S



zur Abw
mittel
DN 7168

Oberfläche
Rechts 2
DN 7168

1995	Datum	Norm
Bearb 18.5.	Ren	
Gepr 19.5.		
Scha		
Norm		

m
Datum

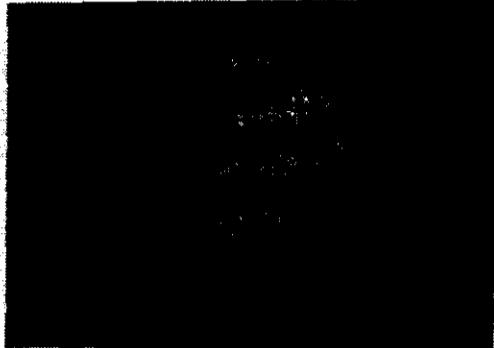
56 36 18 - 8013 (3)

Carl Zeiss

Bl.

appendix 4/3

Lens protocoll/1



MITSUBISHI ELECTRIC
Nr. 1 563618-121 d=5,989
K=211,35 (0,2) E

~~Linsen Nr. 1~~
~~geprüft~~
27.11.85
[Signature]

Kottamia
K-Linse
56 36 18-0131
nach d. Belegem

r = 211,35



MITSUBISHI ELECTRIC
Nr. 2 563618-121 d=5,931
K=211,35 (0,2) E (5,936)

r = 1223,2
→ keine Passung
prüfung möglich



MITSUBISHI ELECTRIC
Nr. 3 563618-121 d=5,964
K=211,35 (0,2) E

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appendix 4/3

Lens protocoll/2



MITSUBISHI ELECTRIC

Nr. 1 5636.18-0.130 d=6,019
R 53,858 (0.3)H

Kottamia

k-Linse

5636 18-0.130

r = 53,858

hoch d. Bolzen



MITSUBISHI ELECTRIC

Nr. 3 5636.18-0.130 d=6,030
R 53,858 (0.2)H

~~Linse Nr. 3~~

~~gerade~~

~~...~~

~~...~~



MITSUBISHI ELECTRIC

Nr. 2 5636.18-0.130 d=6,021
R 53,858 (0.2)E

Measured apex distance

MESSPROTOKOLL ZEISS UMESS

2m Spiegelsyst. K-System fuer Si MANUELLE MESSUNG
 =====
 ZEICHNUNGS NR | AUFTRAGS NR | LIEFERANT/KUNDE | ARBEITSGANG
 563618-8013 | D KOTTAMIA | R APS-KO 2 | messen
 PRUEFER | DATUM | TEIL-NR |
 U. HOLZ | 10.11.95 | 1 |

=====

ADRIRKF	AUFGABE	BEZ	ISYI	ISTMASS	NENNMASS	D.TOL	U.TOL	ABW	UEB
---------	---------	-----	------	---------	----------	-------	-------	-----	-----

=====

1	KREIS A		Y	-102.6336					
			Z	-197.9633					
			D	49.9495					
	4P S/MIN/MAX			0.0015	(4)	-0.0008	(1)	0.0008	
2	KREIS A		Y	-102.8075					
			Z	-197.9663					
			D	49.9362					
	4P S/MIN/MAX			0.0038	(4)	-0.0020	(1)	0.0019	
3	DREHEN RAUM		W	0.0501					
4	NULL-P		Y	-102.9311					
			Z	-197.9684					
5	PUNKT		X	133.3125					
6	NULL-P		X	133.3125					
7	PUNKT		X	195.2979					

----- DISTANZMASS VON SCHEITELPUNKT ZU SCHEITELPUNKT -----

8 7* PUNKT X 195.2979

Soll: 195,32

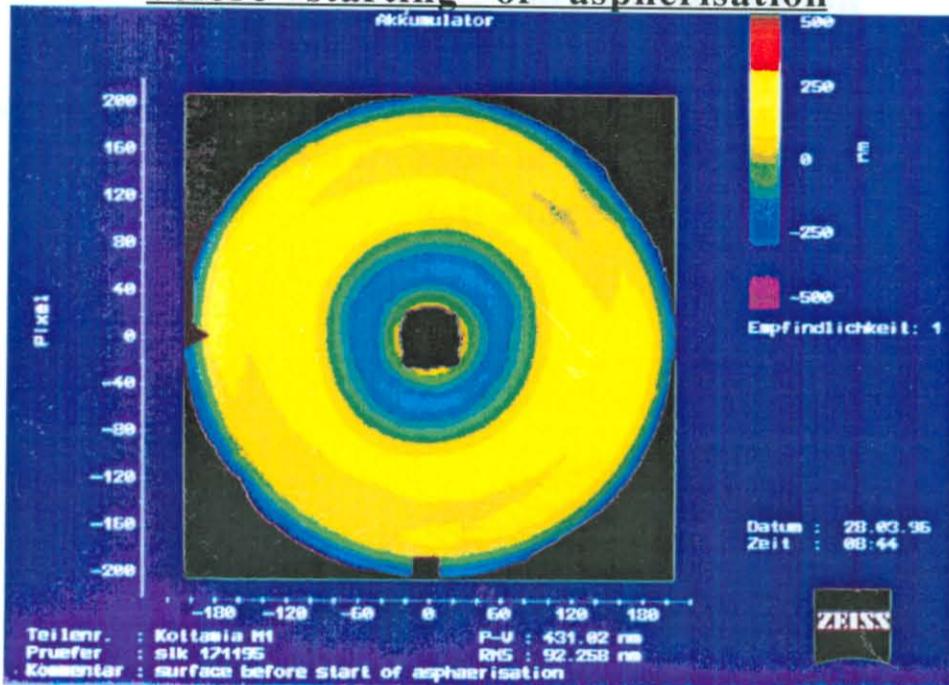
=====

VERWENDBAR ()	NACHARBEIT ()	AUSSCHUSS ()
ABTEILUNG :	UNTERSCHRIFT :	

=====

U-Systeme i.O.
13.11.95 *dfb*

surface topography with respect to the best sphere
before starting of aspherisation

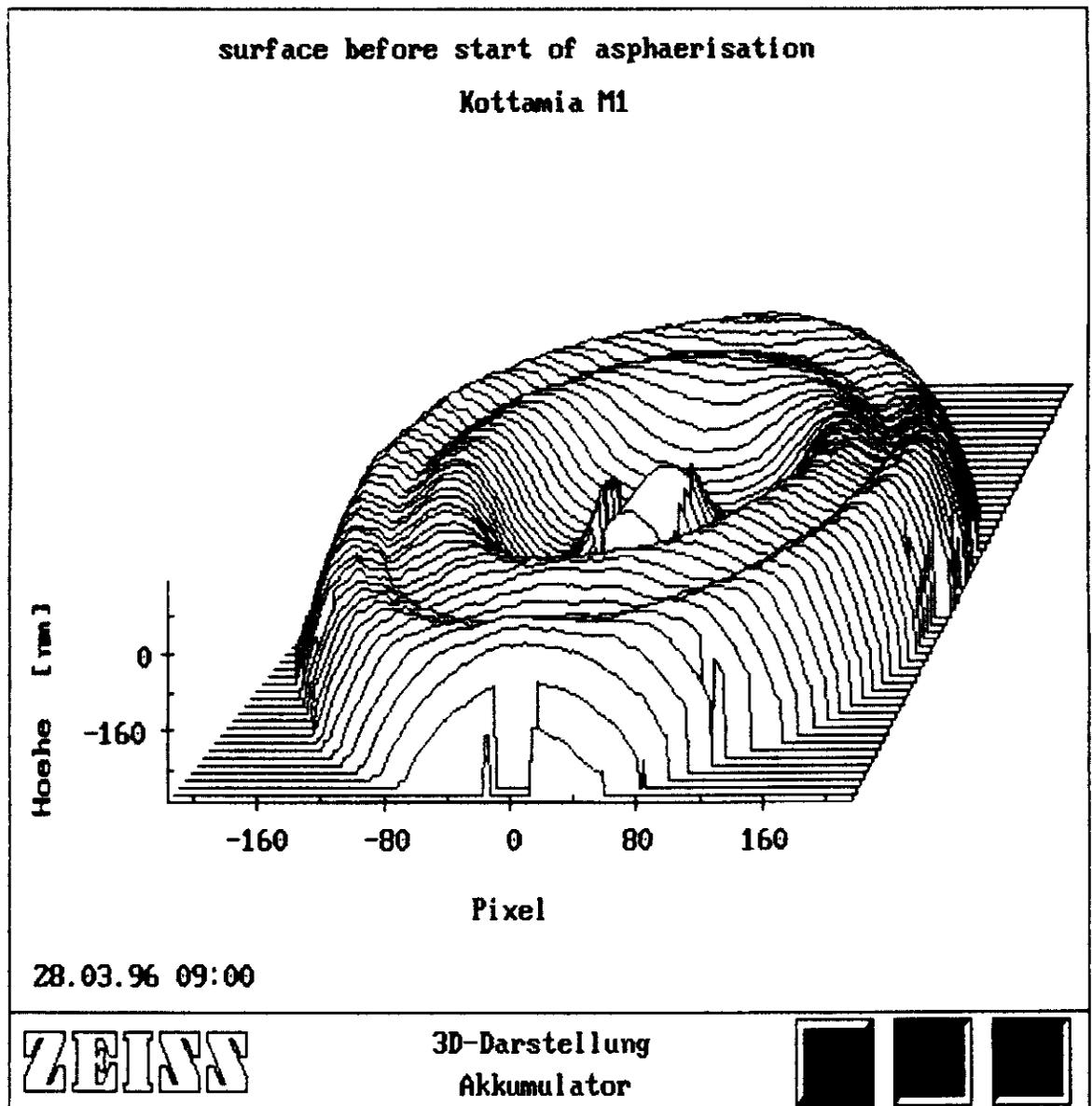


**Zernike - coefficients
after removing of constant, tilt, focus**

Aberration	X-coefficient [nm]	Y-coefficient [nm]
constant	---	---
tilt	---	---
focus	---	---
astigmatism	27	-49
coma	7	14
spherical aberr. h^4	-187	
triangular coma	- 0	- 5
astigmatism h^4	- 13	3
coma h^5	0	2
spherical aberr. h^6	- 12	
4-wave error	26	-17

P-V : 431 nm; RMS : 92.3 nm surface

surface topography with respect to the best sphere
before starting of aspherisation





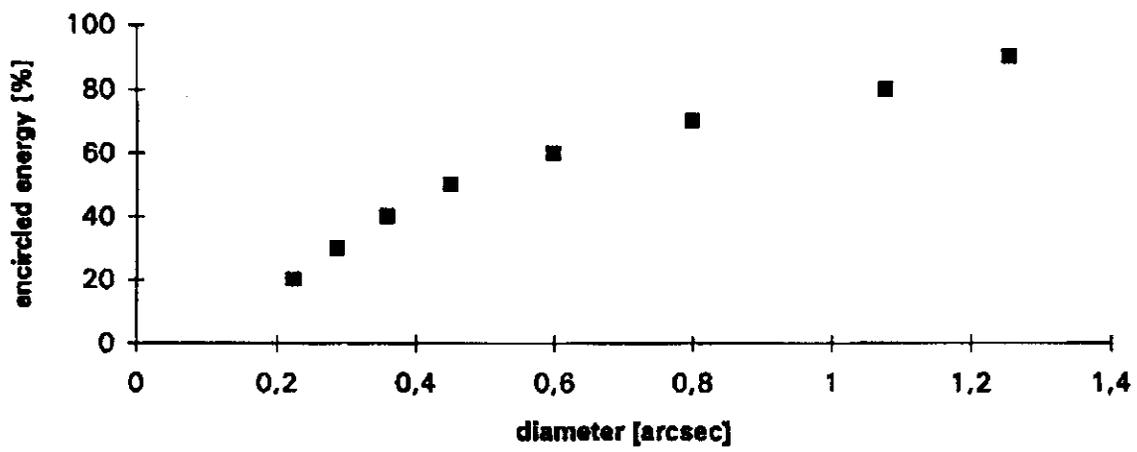
1.88m Optical System Kottamia

Carl Zeiss Jena GmbH
NRIAG Helwan/Cairo

CZJ/Kott-Contract AG 13 95702

appendix 6

Encircled energy of the sphere before starting aspherisation



appendix 7

Radius of sphere before starting aspherisation

Protokoll E-Wert-MessungObjekt: Kottamia MADatum: 16. 11. 95Winkelmessung: $\theta = 6^{\circ} 11' 17''$ Messung der Basis: $D = 1921,1 \text{ mm}$

Pfeilhöhe unter Basis:

$$\text{sag} = \frac{D^2}{8 \cdot R^*} = 25,23 \text{ mm} \quad \text{mit } R^* = 18285 \text{ mm}$$

Abstand zwischen Theodolit und Mittelpunkt der Sphäre:

$$x = 493,6 \text{ mm}$$

Abstand zwischen Theodolit und Höhe Spiegelrand:

$$H = \frac{D}{2} \cdot \frac{1}{\tan\left(\frac{\theta}{2}\right)} = 17770,35 \text{ mm}$$

Somit ergibt sich der Radius zu

$$R = H + \text{sag} + x$$

$$= 17770,35 \text{ mm} + 25,23 \text{ mm} + 493,6 \text{ mm}$$

$$R = \underline{\underline{18289,2 \text{ mm}}}$$

(Toleranz $\pm 2 \text{ mm}$)

Slk/16. 11. 95

**Blank certificate
Schott
OT -0795473**



SCHOTT

Schott Glaswerke Postfach 2480 D-55014 Mainz

SCHOTT GLASWERKE Telefon (06131) 661 Geschäftsbereich
Hattenbergstraße 10 Telex 4 187 9220 sm d Optik
Telegramm
D-55014 Mainz Glaswerk Mainz
West Germany

Certificate / Zertifikat

nach / according to DIN 50049 - 2.3

Nr. / No.: Datum / Date: Bl. / von / Page / from:
OT - 0795473 19.07.95 1/3

Lieferanzeige Nr. / to Delivery Note No.: vom/of: Zeichen des Herstellwerkes / Mark of the Manufacturer Zeichen des Sachverständigen / Inspector's Stamp:

Besteller / Purchaser: Bestellung Nr. / Order No.: Datum / Date:
Carl Zeiss

Unsere Auftrags-Nr. / Our Order-No.: Unsere Abteilung / Our Department: Hausruf / Tel. Int.:
Astro 89982 OGQ/Quality assurance 3563

Erzeugnisform / Product: Lieferbedingungen / Terms of Delivery:
Glass ceramic mirror blank

Werkstoff / Lieferzustand / Quality / Condition of Delivery: Lieferbedingungen und / oder amtliche Vorschriften
Terms of Delivery and / or Official Regulations:

ZERODUR

Pos. / Item:	Anzahl und Einheit / Quantity and Materials:	Erzeugnisform und Abmessungen / Typ / Product and Dimensions / Typ:	Werkstoff / Lieferzustand / Quality / Conditions of Delivery:
1	1 pc.	Mirror blank with center hole Diameter: 1930 ± 2 mm Diameter of center hole: 188 + 1/-0 mm Thickness at the outer edge: 230 + 0.5/-0 mm	Zerodur Melt-No.: 890 094 Annealing-No.: K 28986 K 31230

Es wird bestätigt, daß die Lieferung den Vereinbarungen bei der Bestellung entspricht. / We hereby certify, that the material discribed above has been tested and complies with the terms of the order.

SCHOTT GLASWERKE
Geschäftsbereich Optik
Qualitätssicherung

Quality assurance

SCHOTT
GRUPPE



nach / according to DIN 50049 - 2.3

Nr. / No.: Datum / Date

OT- 0795473 19.07.95

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2/3

limit value

actual value

Geometrical dimensions [mm]

.1	Diameter	1930 ± 2	1931
	Diameter of center hole	188 +1/-0	188.2
	Diameter of concave surface profile	1910 ± 2	1909.7
	Thickness at the outer edge	230 + 0.5/-0	230.3
.2	Flatness (plano side)	≤ 0.1	0.01
.3	Concave radius	18300	18300
	Profile of concave surface	≤ 2.5	0.53
.4	Chamfers at outer edge	7 ± 1 45°	7.5 45°
	Chamfers at center hole (concave side)	8 ± 1 45°	8 45°
	Chamfers at center hole (plano side)	5 ± 1 135°	4.1 135°

Internal quality

1	Inclusions in the uncritical volume		
	Projected area of all inclusions in mm ² per volume of 100 cm ³	≤ 2	< 2
	Maximum diameter of individual inclusions in mm	≤ 5	3.5

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GRUPPE



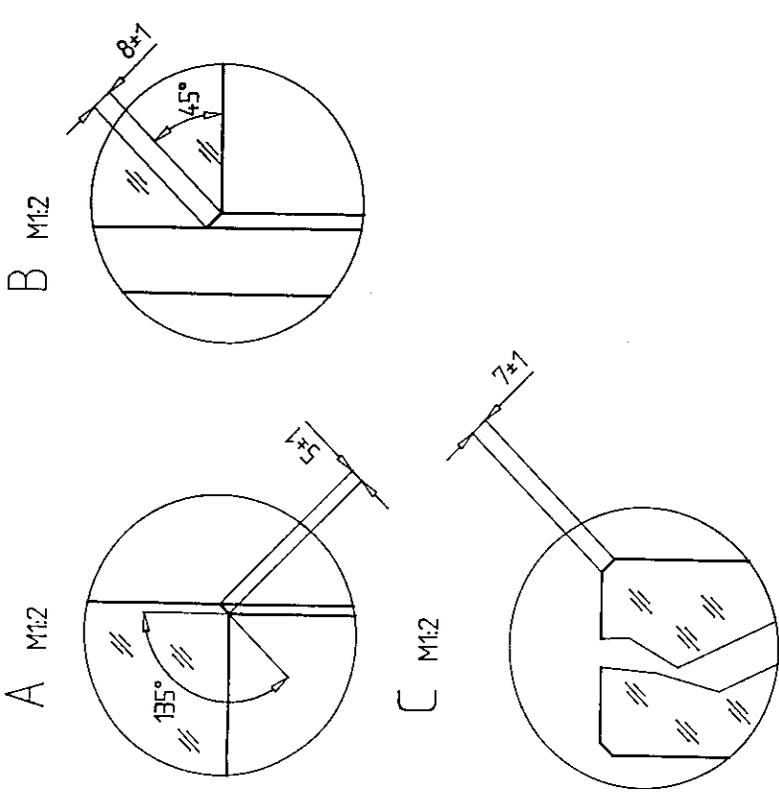
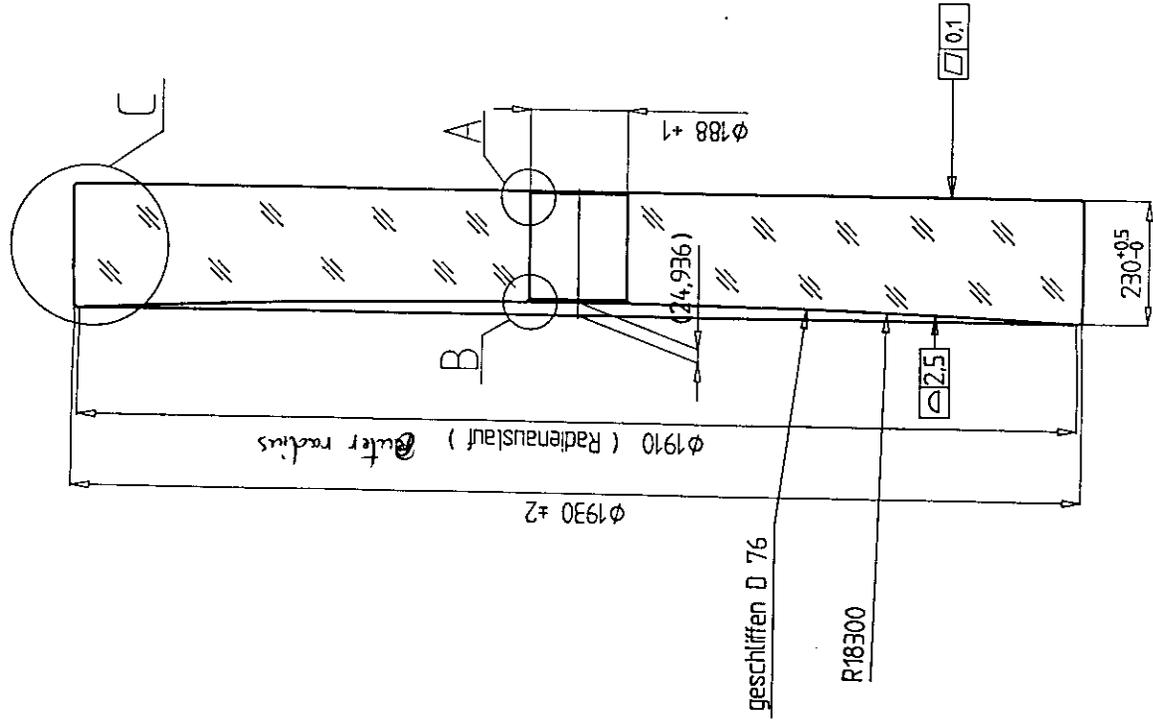
nach / according to DIN 50049 - 2.3

Nr. / No.: OT- 0795473 Datum / Date 19.07.95

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	limit value	actual value
Average number of inclusions per 100 cm ³	≤ 5	< 5
2 Inclusions in the critical volume		
Maximum diameter of individual inclusions in mm	≤ 2	< 1
Average number of inclusions per 100 cm ³	≤ 4	< 4
3 Bulk stress		
	compressive ≤ 10 nm/cm	- 1.5 nm/cm
<u>Surface quality</u>		
Concave surface	D76	D76
plano side	D107	D76
edge surfaces	D64	D64
<u>Material properties</u>		
1.1 Mean coefficient of linear thermal expansion [10 ⁻⁰⁶ K ⁻¹]	0 ± 0.10	0.06
1.2 Homogeneity of the coefficient of thermal expansion [10 ⁻⁰⁶ K ⁻¹]	≤ 0.02	0.01

Diese Unterlage darf nur mit unserer Genehmigung vervielfältigt, verwertet oder weitergegeben werden.



hierzu Spez. TSD 0135.28 Rev. C

Geprüft auf Gerätesicherheit: Sicherheitsstufe: S		Klassifizierungsschlüssel	
Oberflächenbehandlung		Maßstab 1:10	
Zust. Änderung Datum Name GS		Zerodur	
m Datum		Primary mirror	
18		161499:004.07 (3)	
19		Ers. durch	
20		Ers. für	
21		Bl. von	
22		von	
23		ASTRO	
24		KONSTR.-GR.	
25		Name	
26		Datum	
27		Bearb. 217	
28		Gepr.	
29		Scha.	
30		Norm	
31		Name	
32		Hellem	
33		Name	
34		Oberfläche	
35		DIN ISO	
36		1302	
37		zul. Abw.	
38		mittel	
39		DIN 7168	
40		DIN 9284	
41		1.05	
42		0.05	

1 2 3 4

**Measured weight
of
Kottamia 1,88m Primary M1**



20m Primary Kottamia

Wiegen des 2.0m Kottamia-Spiegels

Ort: Astro-Halle Bau 1/a
Datum: 20.3.1996 10¹⁵ Uhr
anwesend: Heiko Bäuerle, Willi Bäuerle, Erdmann, Knh

Messgerät: Kranwaage TIGRIP
ZEISS Nr. 2700902
DK.Nr. 3884
ID.Nr. 26438 LMB Nr. 91010791
TYP TKS Bj.: 01.04.1991
Tragfähigkeit 2,5 to
Hersteller: Schmidt, Kranz & Co. GmbH
3425 Walkenried
Tel. 05525/201-0

Prüfgenauigkeit: +0,2%

Messvorgang:		digitale Anzeige
1.)	Waage + Schekel nullen	000 kg
2.)	Aushebevorrichtung	101 kg
3.)	Spiegel + Aushebevorrichtung	1701 kg
4.)	Aushebevorrichtung	101 kg
5.)	Waage + Schekel	000 kg

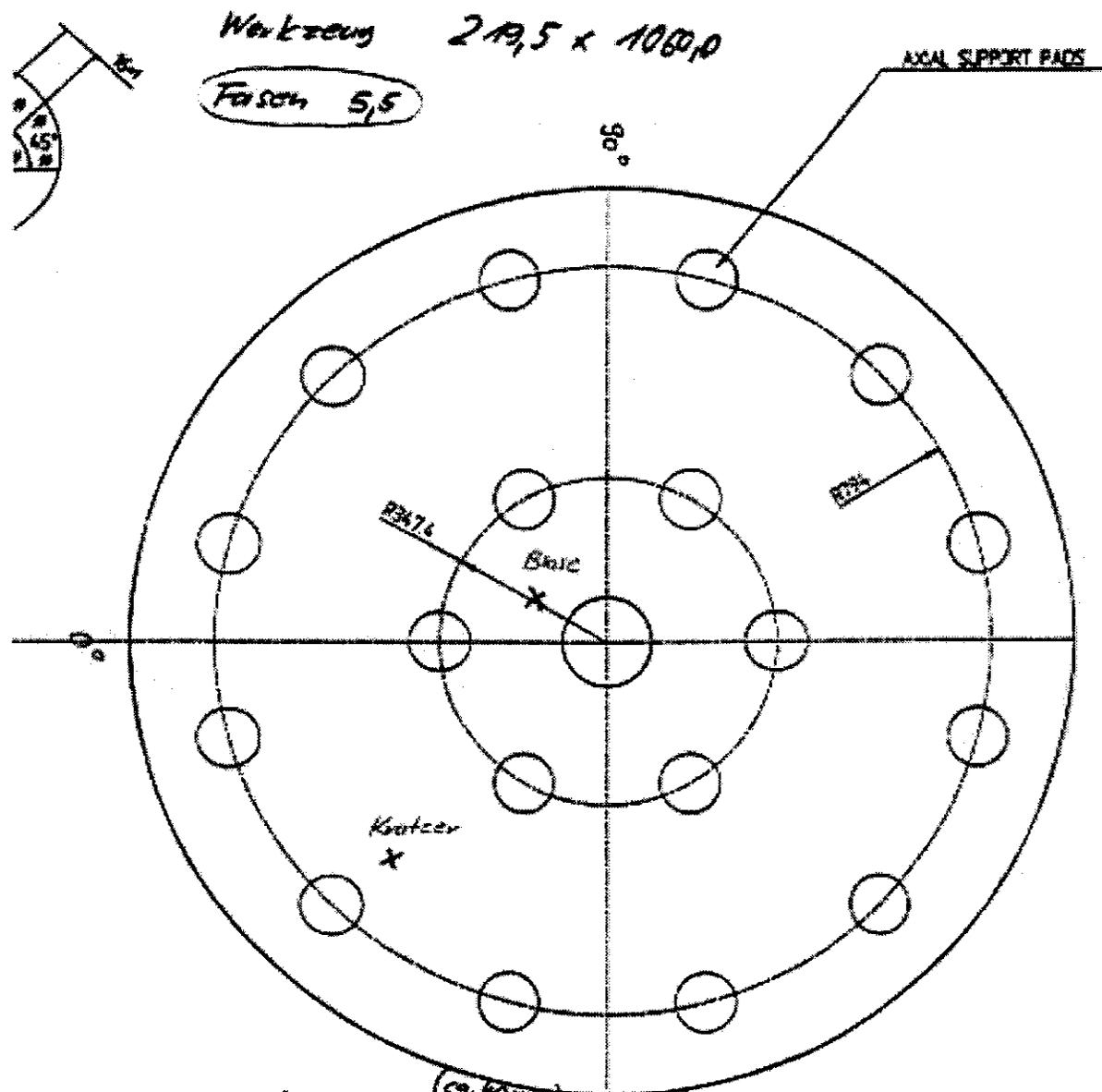
Spiegelgewicht: 1600 kg - 5kg

Bestätigung der Messung
Oberkochen, den 22.3.1996


Dipl.Ing. E.-D. Knohl
CARL ZEISS
Abt. Weltraumtechnik



Cleanliness of optical surface



Ein langer Analytische
 -7. 2. Keine ungenutzte Fläche
 sichtbar, ungefähre Lage mit
 Kreuz gekennzeichnet!
 7.2.36 Abstände der Linsen

Kottamia

Influence of E-value tolerances

Math-F 71/95-12-19

2 m Teleskop KOTTAMIA.

Einfluß der E-Wert Toleranzen auf die Fokusslage
im Teleskop.

=====

1. Bei der Fertigung der Spiegel ist ein Abstand zwischen K-System und Prüfling vorgegeben.

Abweichungen vom Sollwert dieser Entfernung werden als E-Wert-Toleranzen bezeichnet.

E-Wert-Toleranzen führen bei NULL-PASSE-Fertigung vor allem zu Änderungen des Scheitelradius der Spiegel.

2. Im Teleskop führen die mit E-Wert-Toleranzen gefertigten Spiegel zu Änderungen der spezifizierten Sollwerte.

3. Es sind folgende Alternativen zu unterscheiden:

- 3a. die mit E-Wert-Tol. gefertigten Spiegel werden mit Sollabstand im Teleskop eingebaut. dann ergeben sich folgende Abweichungen im Teleskop:

$$\Delta g(\text{mm}) = 7.00 * \Delta E1(\text{mm}) - 3.59 * \Delta E2(\text{mm})$$

$$\Delta W(\text{lambda}) = -0.014 * \Delta E1(\text{mm}) + 0.0076 * \Delta E2(\text{mm})$$

darin bedeuten:

$\Delta g(\text{mm})$: Abweichung der Fokusslage in mm;
 $\Delta W(\text{lambda})$: sphär. Aberr. in Einheiten von 633 nm,
 $\Delta E1, \Delta E2$: E-Wert-Tol. für S1 und S2 in mm.

3b. die mit E-Wert-Tol. gefertigten Spiegel werden so eingebaut, daß die Soll-Fokus-Lage erreicht wird. dann ergeben sich folgende Abweichungen im Teleskop:

$$\Delta e(\text{mm}) = 0.467 * \Delta E1(\text{mm}) - 0.248 * \Delta E2(\text{mm})$$

$$\Delta W(\lambda) = -0.0039 * \Delta E1(\text{mm}) + 0.0024 * \Delta E2(\text{mm})$$

darin bedeuten:

$\Delta e(\text{mm})$: Änderung der Spiegelseparation im Teleskop;

$\Delta W(\lambda)$: sphär. Aberr. in Einheiten von 633 nm

$\Delta E1, \Delta E2$: E-Wert-Tol. für S1 und S2 in mm.

3c. die mit E-Wert-Tol. gefertigten Spiegel werden so eingebaut, daß ein aberrationsfreier Fokus erzeugt wird; dann ergeben sich folgende Abweichungen im Teleskop:

$$\Delta e(\text{mm}) = 0.657 * \Delta E1(\text{mm}) - 0.366 * \Delta E2(\text{mm})$$

$$\Delta g(\text{mm}) = -2.77 * \Delta E1(\text{mm}) + 1.83 * \Delta E2(\text{mm})$$

darin bedeuten:

$\Delta e(\text{mm})$: Änderung der Spiegelseparation in mm;

$\Delta g(\text{mm})$: Änderung der Fokuslage in mm;

$\Delta E1, \Delta E2$: E-Wert-Tol. für die Spiegel S1 und S2

4. Beispiel:
=====

wir nehmen an, der S1 sei mit einer E-Wert-Tol. von $\Delta E1 = 10. \text{ mm}$,
der S2 mit einer E-Wert-Tol. von $\Delta E2 = 5. \text{ mm}$
gefertigt worden.

Dann sind folgende Alternativen im Teleskop möglich:

4a. Spiegelseparation $e = 6993.8 \text{ mm}$ (Sollwert)

Abweichung von Sollfokus: $\Delta g = 52. \text{ mm}$
sphär. Aberr. $\Delta W = 0.1 \text{ Lambda}$ (633 nm)

4b. Spiegelseparation $e = 6997.23 \text{ mm}$ ($\Delta e = 3.43 \text{ mm}$)

Abweichung vom Sollfokus: $\Delta g = 0. \text{ mm}$
sphär. Aberr. $\Delta W = 0.027 \text{ Lambda}$ (633)

4c. Spiegelseparation $e = 6998.54 \text{ mm}$ ($\Delta e = 4.74 \text{ mm}$)

Abweichung vom Sollfokus: $\Delta g = -18.6 \text{ mm}$
sphär. Aberr. $\Delta W = 0.$

5. Bisher waren für beide Spiegel E-Wert-Toleranzen in gleicher Richtung (beide positiv) angesetzt worden. Der ungünstigere Fall:

$$\Delta E1 = 10. \text{ mm}; \quad \Delta E2 = -5. \text{ mm}$$

ergäbe bei Einhaltung der Soll-Fokuslage hinter dem S1 einen Teleskopaufbau mit:

Spiegelseparation $e = 6999.71 \text{ mm}$ ($\Delta e = 5.91 \text{ mm}$)

sphär. Aberr. $\Delta W = 0.05 \text{ (lambda)}$ (633 nm)

dh.

die spezifizierte Fokuslage hinter dem S1 kann eingehalten werden, wenn der Spiegelabstand um 5.9 mm vergrößert wird.

Die eingeführte Aberration kann dabei völlig vernachlässigt werden.