

# Null corrector for 1-m $f/3.5$ primary

## Optical design and analysis

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### **Introduction**

This report gives the optical design and analysis of a two-element Offner-type null corrector for a 1-m primary mirror. The optical system assumes an interferometer that provides a point source, a 50 mm diameter relay lens, and a 30 mm diameter field lens. Both lenses are plano-convex, purchased from Melles Griot. The overall length of the null corrector is about 255 mm. A detailed analysis of the sensitivity to manufacturing errors shows expected errors in the surface measurement of 3 nm rms spherical aberration (conic constant uncertainty of 0.001) and 11 nm error after removing the spherical aberration. No hologram will be used for this test.

The accuracy of the surface measurement using the null lens is shown in Table 1.

**Table 1.** Accuracy for primary mirror testing

	Test accuracy
Radius of curvature R	$R = 7000 \pm 2$ mm
Conic constant K	$K = -1.0500 \pm 0.0013$
Rms figure (including SA)	11.6 nm rms
rms figure (with SA removed)	11.3 nm rms

### **Optical design**

The null corrector consists of a two-element Offner type null lens to be used with light from a HeNe laser. Plano-convex lenses that can be purchased from Melles Griot were chosen to minimize the cost. It is expected that the lenses will be further polished to improve the optical figures. The optical design is nearly perfect, with  $0.0002 \lambda$  rms residual wavefront. The prescription for the null lens is given in Table 2. The interferometer is not included in this design. The prescription shows the full double-pass of the test. The point source is at surface 0 and its image reflected from the mirror is at surface 12. The relay lens is at surfaces 1,2 and 10,11. The field lens is at surfaces 3,4 and 8,9. Paraxial focus is at surfaces 5 and 7. And the primary mirror is at surface 6

**Table 2.** Prescription of null lens (units in mm)

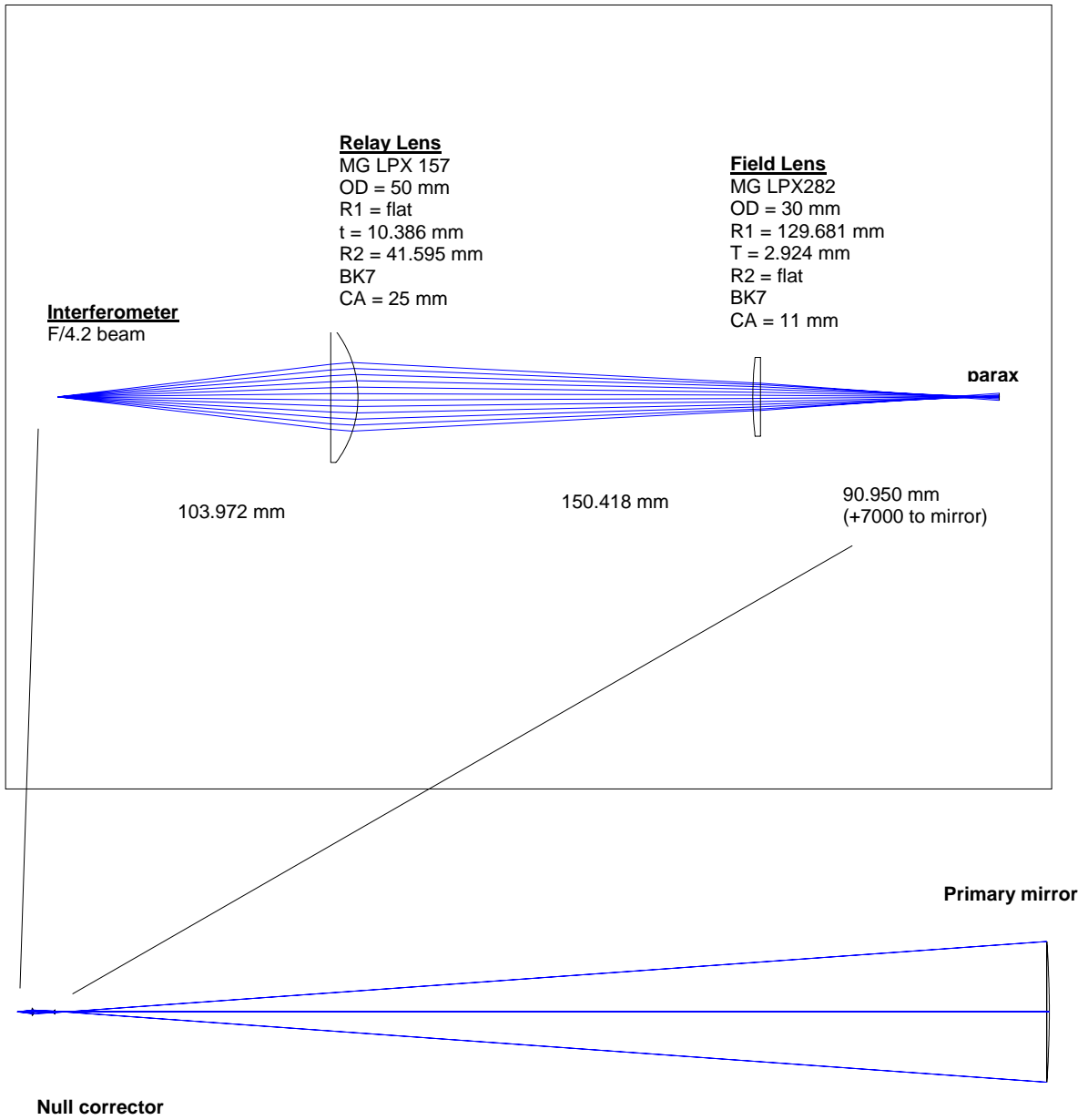
Surface	Radius	Thickness	Glass	Diameter	Conic
0	Infinity	103.972		0	0
1	Infinity	10.386	BK7	50	0
2	-41.595	150.418		50	0
3	129.681	2.924	BK7	30	0
4	Infinity	90.950		30	0
5	Infinity	7000		2.76	0
STO	-7000	-7000	MIRROR	1010	-1.05
7	Infinity	-90.950		2.76	0
8	Infinity	-2.924	BK7	30	0
9	129.681	-150.418		30	0
10	-41.595	-10.386	BK7	50	0
11	Infinity	-103.972		50	0
IMA	Infinity	0		0	0

#### INDEX OF REFRACTION DATA:

BK7 1.515088 @ 632.834 nm

The optical design shows that there are no troublesome ghost reflections. The null lens is drawn in Figure 1.

**Figure 1.** Layout of null lens for 1-m f/3.5 K - -1.05



### **Tolerance analysis**

A thorough tolerance analysis was performed on this test system. The effects of most errors such as spacing, curvature, index, etc. were determined by direct simulation. It is assumed that the stated tolerances correspond to the *measurement* accuracy of the quantity. If the thickness and radii depart from the design values, but are accurately known, then the spacing can be adjusted to compensate.

The assumptions for accuracy are summarized in Table 3 and a complete table is given in Table 4. Charts of the relative contributions from each component are given in Figs. 2 and 3.

**Table 3.** Accuracy for null lens fabrication

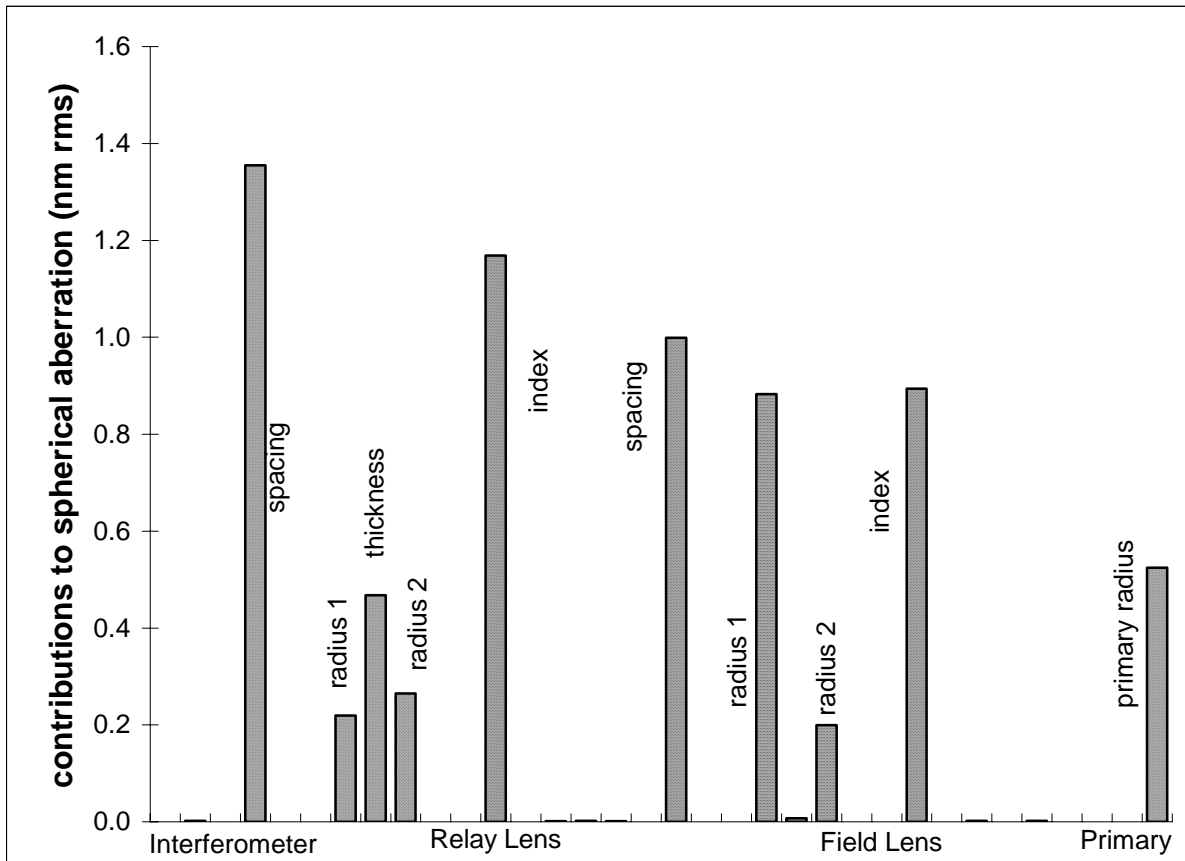
<u>Quantity</u>	<u>Tolerance</u>
Lens spacing	50 $\mu\text{m}$
Lens thickness	25 or 50 $\mu\text{m}$
Radius of curvature	1 fringe power or 25 $\mu\text{m}$ (whichever is smaller)
Flatness	$\lambda/4$
Surface figures	0.008 $\lambda$ rms interferometer 0.015 $\lambda$ rms lenses
Index of refraction	$\pm 0.0002$ (Grade A BK7)
Index Inhomogeneity	0.25 E-6 rms (H4 grade)
Wedge in lenses	50 $\mu\text{m}$
Decenter in mounting	50 $\mu\text{m}$
Tilt in mounting	50 $\mu\text{m}$
Primary radius of curvature	2 mm

The spherical aberration was separated from other errors for this analysis.

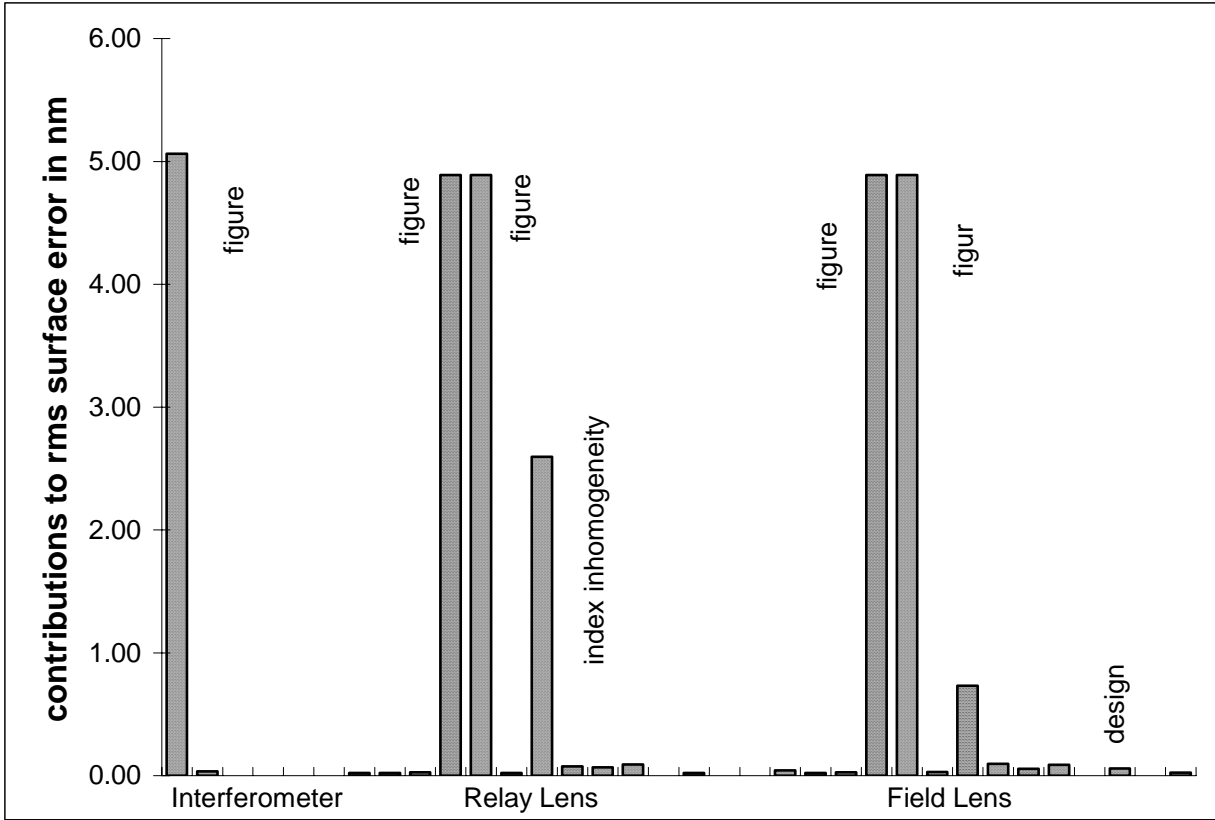
**Table 4.** Tolerances for null lens

	units	Design value	uncertainty	Spherical aberration (nm rms)	Figure (nm rms)
<b>Interferometer</b>					
Irregularity (rms)	waves		0.008		5.06
Decenter	μm		0.050	0.00	0.03
<b>Airspace</b>					
	mm	103.972	0.05	1.36	0.00
<b>Relay Lens:</b>					
Curvature 1	/mm	0.00E+00	2E-06	0.22	0.02
Thickness	mm	10.386	0.025	0.47	0.02
Radius 2	mm	41.595	0.025	0.26	0.03
Irregularity 1 (rms)	waves		0.015		4.89
Irregularity 2 (rms)	waves		0.015		4.89
Index		1.51509	2E-04	1.17	0.02
Inhomogeneity	rms		2.5E-7		2.60
Wedge	μm		50	0.00	0.07
Decenter	μm		50	0.00	0.07
Tilt	μm		50	0.00	0.09
<b>Airspace</b>					
	mm	150.418	0.050	1.00	0.02
<b>Field Lens:</b>					
Radius 1	mm	129.681	0.050	0.88	0.04
Thickness	mm	2.924	0.050	0.01	0.02
Curvature 2	/mm	0.00E+00	1.4E-06	0.20	0.03
Irregularity 1 (rms)	waves		0.015		4.89
Irregularity 2 (rms)	waves		0.015		4.89
Index		1.51509	2E-04	0.89	0.03
Inhomogeneity	rms		2.5E-7		0.73
Wedge	μm		50	0.00	0.10
Decenter	μm		50	0.00	0.06
Tilt	μm		50	0.00	0.09
Residual Wavefront	waves		0.000182	0	0.06
Primary Radius	mm	7000	2	0.52	0.02
<b>RSS</b>				<b>3</b>	<b>11.34</b>

This spherical aberration corresponds to conic constant uncertainty of 0.0013. The total measurement error from the null lens is 11.7 nm rms, including the spherical aberration.



**Figure 2.** Contributions to spherical aberration in the test



**Figure 3.** Contributions to rms surface measurement error