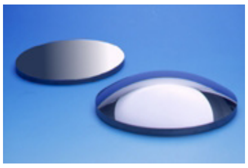
Silicon Elements for IR Objective Lenses



TYDEX produces a wide range of elements made of silicon. We ensure strong control on every step of element production, from material selection to the measurement of obtained parameters of polished elements and coating characteristics. That is especially important in the manufacturing of precision imaging systems. This type of approach to the production of a set of large silicon optics for IR objective is described below.

The objective is intended for operating in two middle IR bands: 1.6-3.0 µm and 3.5-5.5 µm. Its design incorporates 17 elements: 14 meniscus and plano-convex lenses with diameters from 10 mm to 210 mm and 3 plates with dimensions up to 134x198 mm.

When manufacturing such multi-element imaging devices two important points should be taken into consideration: transmittance of the whole system and image distortion. These parameters depend on material quality (i) and surface accuracy (ii). Below we discuss our approach to control of these parameters (we will not touch the third critical point - coating parameters).

Material selection and control

For imaging systems the right choice of material is of utmost very importance. Defects in the material can cause image distortion and violate the system operation. This is the reason why so much attention is paid to selecting the material and its control.

To provide the proper quality of material, silicon ingots with special parameters (dislocation-free optical grade monocrystalline Cz-Si with high homogeneity and transparency in the working range) were grown. After a few required ingots with diameter up to 219mm were ready the quality of material (resistance homogeneity, dislocation density, transmittance in the working range) is being controlled on samples prepared from each ingot. The typical transmission curve is presented here.

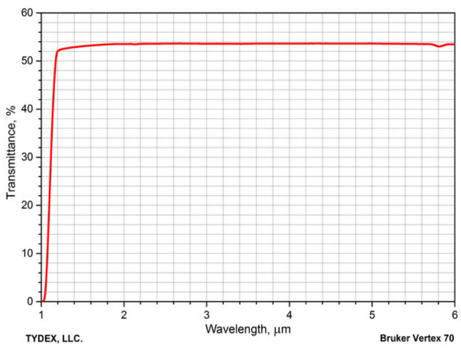


Fig. 2. Silicon transmission in the 1.1 - 5.7 µm spectral range. Sample thickness is 10 mm.

Surface accuracy control

As mentioned above, the second important parameter that should be considered is surface errors. Modern equipment allows to carry out complete interferometric control of a the whole surface or any part of it. Computer data processing enables us to obtain detailed information about different kinds of errors: regular errors (astigmatism, zonal error, coma), local errors, peak-to-valley value etc. In addition, representation of errors becomes easy to interpret.

For interferometric control Fizeau scheme is applied, λo = 632.8 nm (HeNe laser line). Additional equipment such as telescopic expanders and measuring objectives is used if required by surface shape and radius of curvature. Evaluation of the form error of a surface is being carried out in phase mode by means of measuring the deformation of the wavefront reflected from the controlled surface compared to test reference surface. Specialised integrated software is used to create phase data arrays and their further power polynomial approximation for surface error calculations.

Here we present as examples the results of such control for 2 surfaces: 1 - concave surface of meniscus D210 mm lens, and 2 - plane surface of 198 x 134 mm plate.

1. Interferometric measurements of errors of meniscus lens D210 mm

Fig. 3. Interferogram of surface.

Controlled surface:

concave R = -206.99mm

Test area: clear aperture central D206mm

Measurement units: microns

Regular errors:

D=.080 LX=2.839 LY=-.013 C=2.829 RMS(W)= .031 A=.050 FIA= .354 RMS(W-A)= .023 FA= .442 B0=-.025 RZ=.037 RMS(W-Z)= .029 FZ= .131 B2= .149 B4=-.149 C=.110 FIC=164.892 RMS(W-C)=.028 FC= .178

Local errors:

R= .139 RMS(M)= .015

Parameters of surface:

RMS	MIN	MAX	R	STRL	STRH
.031	-.144	.092	.237	.964 .	988

X : -1.000 .000

Y : .000 -1.000

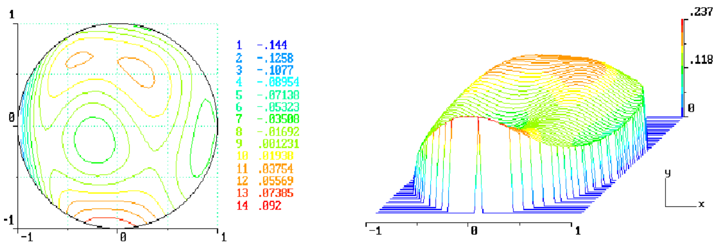


Fig.4 Reconstructed wavefront topography presented at planar and 3-d plots

2. Interferometric measurements of errors of plane parallel plate 198x134 mm

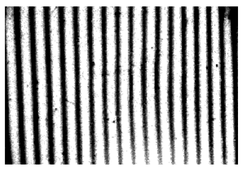


Fig. 5. Interferogram of surface.

The surface undergoes measurements in 2 areas: center zone of dimensions 70 x 70 mm (approximately the area occupied by incident ray) and the whole aperture 194 x 130 mm. Controlled surface S1: plane R = infinity

A/ Test area: 70 x 70 mm

Measurement units: microns

Reference surface: plane

Regular errors:

D=.000 LX=2.811 LY=.053 C=2.045 RMS(W)= .024 A=.104 FIA=81.477 RMS(W-A)=.011 FA= .787 B0=-.020 RZ=.083 RMS(W-Z)=.016 FZ= .561 B2= .039 B4= .117 C=.022 FIC=50.186 RMS(W-C)=.023 FC= .014

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TYDEX®

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Local errors:

R= .077 RMS(M)= .012

Parameter of surface:

RMS	MIN	MAX	R	STRL	STRH
.024	-.036	.076	.112	.978	.993

X : -.200 -.680

Y : -.480 .440

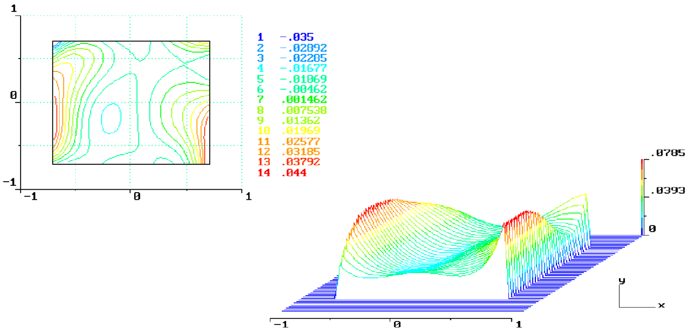

Fig.6 Reconstructed wavefront topography presented at planar and 3-d plots

B/ Test area: 194 x 130mm

Measurement units: microns

Reference surface: plane

Regular errors:

D=.000 LX=1.447 LY=.033 C=.964 RMS(W)=.014 A=.045 FIA=82.986 RMS(W-A)= 010 FA= .489 B0=-.014 RZ=.023 RMS(W-Z)= .012 FZ= .235 B2=.064 B4=-.045 C=.012 FIC=173.740 RMS(W-C)=.014 FC= .009

Local errors:

R= .076 RMS(M)= .007

Parameter of surface:

RMS	MIN	MAX	R	STRL	STRH
.014	-.035	.044	.079	.993	.998

X : -.680 .680

Y : .680 -.680

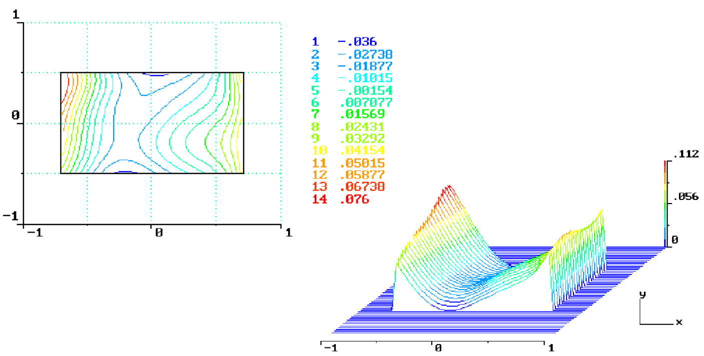

Fig.7 Reconstructed wavefront topography presented at planar and 3-d plots

The detailed description of the notation

Regular errors:

Parameters of reference surface: D - sag of the sphere at the edge of pupil (D=0 for plane reference surface), Lx, Ly - tilt of sphere,

C - constant

RMS(w) - RMS of wavefront with regard to reference surface

A, FIA- value and angle of turn of astigmatism

RMS(w-a) - RMS of wavefront beyond astigmatism

FA - statistic estimation of the contribution of astigmatism to the complete wavefront distortion

B0,B2,B4,... - coefficients of zonal error at corresponding power

P(p*p = x*x + y*y) or at Zernike polynomial

RZ - span of zonal error

RMS(w-z) - RMS of wavefront except zonal error

FZ - statistic estimation of the contribution of zonal error to the complete wavefront distortion

C, FIC - value and angle of turn of coma error

RMS(w-c) - RMS of wavefront except coma

FC - statistic estimation of the contribution of coma error to the complete wavefront distortion

Local errors (errors of wavefront with power higher than 4th):

R - span of local errors

RMS(M) - RMS of local errors

Parameters of surface under control:

RMS - RMS of surface error (RMS = RMS(w))

MIN - minimal value of surface (valley)

MAX - maximal value of surface (peak)

R - span (PtV)

STRL- lower bound of Schtrel number

STRM - upper bound of Schtrel number

X,Y- test area coordinates

Such thorough control on each step of production can guarantee that all parameters of the item meet specifications required by customer and that the device will operate in a proper way.

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