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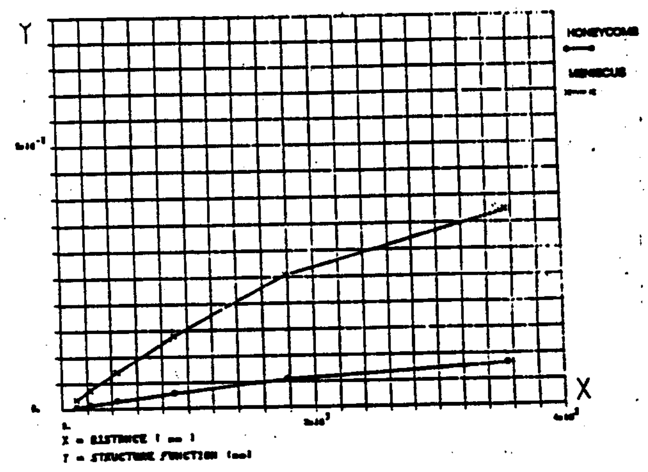
COLUMBUS PROJECT

MIRROR BLANK 8. mt diam F1.2

HONEYCOMB - MENISCUS MIRROR BLANK COMPARISON



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1. INTRODUCTION

Object of this report is the stiffness comparison between the Columbus honeycomb mirror blank versus an 8m f/1.2 meniscus. Astigmatic deformations have been considered.

For the honeycomb mirror analysis we have used the model described in report N. 104 Rev 0, 1988, February 29th.
For the meniscus we have prepared a finite element model using the "upper plate" of the honeycomb one in order to have the same node density.
In figure 1 a plot of the meniscus mesh is reported.
The meniscus geometrical characteristics are:

- External diameter = 8000. mm
- Internal hole diameter = 1200. mm
- Thickness = 200. mm

The material is silica, and it has the follwing mechanical characteristics:

- Young modulus = 74500. $\frac{N}{mm^2}$
- Poisson modulus = 0.17

These values are different from those used for borosylicate honeycomb mirror (see Rep. N.104), anyway we can assume that the meniscus deflections are inversely proportional to Young modulus.

In figure 2 is reported the loading condition applied to both the mirrors.

Loads and mirror geometry have two hortogonal symmetry axis so both the models are relative to a quarter of the mirror with symmetry constraints along the two edges. In order to avoid rigid body movements in axial direction we put an axial constraint on the node 4613. Since the loads are self-balanced no reaction is exerted by the constraint so, since from the results are subctracted the rigid movements, the axial constraint position doesn't affect the problem.

The results obtained from the meniscus finite element analysis have been compared with the deflections computed using the expression:

$$z(r,\theta) = \frac{24\ F\ \cos 2\theta}{\pi\ E\ t^3}\ \frac{1-\nu^2}{3+\nu}\left[\frac{r^2}{1-\nu} - \frac{r^2}{6a^2}\right]$$

obtained from the paper by Nelson et al. (Proc. SPIE 332 212 1982)

where

- a = meniscus radius
- F = force value
- t = meniscus thickness
- E = Young modulus
- ν = Poisson modulus

Since the dead weight doesn't act and the applied loads are parallel to the paraboloid axis, the in-plane displacement components (X-Y direction of figure 1) doesn't affect the problem.
The only meaningful displacements are the axial ones (Z direction).

2. MENISCUS RESULTS

The optical performances of the meniscus, obtained by the finite element analysis, are reported in next table:

RMS - PEAK TO VALLEY	
RMS as to the bestfit paraboloid	$0.283\ 10^{-2}$ mm
Axial Displacement Peak to Valley	$0.1368\ 10^{-1}$ mm

In figure 3 are plotted the isocontours (step=500. nm) of the axial component of the displacement as to the bestfit paraboloid.
In order to check the algebraic expression previous reported we computed the same quantities using this expression and we obtained:

RMS - PEAK TO VALLEY	
RMS as to the bestfit paraboloid	$0.281\ 10^{-2}$ mm
Axial Displacement Peak to Valley	$0.1303\ 10^{-1}$ mm

In figure 4 are plotted the isocontours (step=500. nm) of the axial component of the displacement, computed using the algebraic formula. The agreement with the finite element results is very good.

All the results reported in the following pages are those obtained by the finite element analysis.

The first 45 coefficient values of the upper plate strain expansion in Zernike polynomial serie are reported in the following table:

ZERNIKE POLYNOMIAL COEFFICIENTS		
$c_{00} = 0.000$	$c_{11} = 0.000$	$d_{11} = 0.000$
$c_{20} = 0.000$	$c_{22} = 6.83\ 10^{-3}$	$d_{22} = 0.000$
$c_{31} = 0.000$	$d_{31} = 0.000$	$c_{33} = 0.000$
$d_{33} = 0.000$	$c_{40} = 0.000$	$c_{42} = -2.30\ 10^{-4}$
$d_{42} = 0.000$	$c_{44} = 0.000$	$d_{44} = 0.000$
$c_{51} = 0.000$	$d_{51} = 0.000$	$c_{53} = 0.000$
$d_{53} = 0.000$	$c_{55} = 0.000$	$d_{55} = 0.000$
$c_{60} = 0.000$	$c_{62} = 1.30\ 10^{-4}$	$d_{62} = 0.000$
$c_{64} = 0.000$	$d_{64} = 0.000$	$c_{66} = 1.69\ 10^{-4}$
$d_{66} = 0.000$	$c_{71} = 0.000$	$d_{71} = 0.000$
$c_{73} = 0.000$	$d_{73} = 0.000$	$c_{75} = 0.000$
$d_{75} = 0.000$	$c_{77} = 0.000$	$d_{77} = 0.000$
$c_{80} = 0.000$	$c_{82} = 1.97\ 10^{-4}$	$d_{82} = 0.000$
$c_{84} = 0.000$	$d_{84} = 0.000$	$c_{86} = -1.19\ 10^{-5}$
$d_{86} = 0.000$	$c_{88} = 0.000$	$d_{88} = 0.000$

The Zernike polynomial expressions are reported in Appendix A.
Clearly the most important Zernike polynomials are those containing
$\rho^2 - \rho^4 - cos\,2\theta$
in accordance with the algebraic expression of the axial displacements.
The Zernike polynomial:
$c_{22}\,\rho^2\,cos\,2\theta \;=\; 6.82\;10^{-3}\,\rho^2\,cos\,2\theta$
allows to estimate very closely the Peak to Valley value, we obtain in fact $1.366\;10^{-2}$ and the "true value" is $1.368\;10^{-2}$.

The results related to the structure function are reported in the following table:

STRUCTURE FUNCTION			
DISTANCE cell side	COUPLE NUMBER	AVERAGE VALUE (mm)	STANDARD DEVIATION (mm)
1 side	12944	$-0.41\;10^{-4}$	$0.181\;10^{-3}$
2 sides	12702	$-0.83\;10^{-4}$	$0.360\;10^{-3}$
4 sides	12446	$-0.18\;10^{-3}$	$0.712\;10^{-3}$
8 sides	12272	$-0.42\;10^{-3}$	$0.139\;10^{-2}$
16 sides	9977	$-0.92\;10^{-3}$	$0.254\;10^{-2}$
32 sides	6351	$-0.25\;10^{-2}$	$0.373\;10^{-2}$

In figure 8 is reported the Structure Function "distance - standard deviation".

In figure 5 are plotted the areas around the focus related to an assigned percentage of the total energy; such areas have been plotted for the pergentages from 10.% to 100.% step 10.%. From this figure we obtain that the 90. % of the total energy is included in a "cone" having 2.5 arcsec angle.

3. HONEYCOMB RESULTS

The optical performances of the honeycomb mirror blank are reported in next table:

RMS - PEAK TO VALLEY	
RMS as to the bestfit paraboloid *Axial Displacement Peak to Valley*	$0.614\ 10^{-3}$ mm $0.288\ 10^{-2}$ mm

In figure 6 are plotted the isocontours (step=500. nm) of the axial component of the displacement as to the bestfit paraboloid.

The first 45 coefficient values of the upper plate strain expansion in Zernike polynomial serie are reported in the following table:

ZERNIKE POLYNOMIAL COEFFICIENTS		
$c_{00} = 0.000$	$c_{11} = 0.000$	$d_{11} = 0.000$
$c_{20} = 0.000$	$c_{22} = 1.48\ 10^{-3}$	$d_{22} = 0.000$
$c_{31} = 0.000$	$d_{31} = 0.000$	$c_{33} = 0.000$
$d_{33} = 0.000$	$c_{40} = 0.000$	$c_{42} = -6.58\ 10^{-5}$
$d_{42} = 0.000$	$c_{44} = 0.000$	$d_{44} = 0.000$
$c_{51} = 0.000$	$d_{51} =0.000$	$c_{53} = 0.000$
$d_{53} = 0.000$	$c_{55} = 0.000$	$d_{55} = 0.000$
$c_{60} = 0.000$	$c_{62} = 3.51\ 10^{-5}$	$d_{62} = 0.000$
$c_{64} = 0.000$	$d_{64} = 0.000$	$c_{66} = 3.40\ 10^{-5}$
$d_{66} = 0.000$	$c_{71} = 0.000$	$d_{71} = 0.000$
$c_{73} = 0.000$	$d_{73} = 0.000$	$c_{75} = 0.000$
$d_{75} = 0.000$	$c_{77} = 0.000$	$d_{77} = 0.000$
$c_{80} = 0.000$	$c_{82} = 4.14\ 10^{-5}$	$d_{82} = 0.000$
$c_{84} = 0.000$	$d_{84} = 0.000$	$c_{86} = 0.000$

ZERNIKE POLYNOMIAL COEFFICIENTS		
$d_{86} = 0.000$	$c_{88} = 0.000$	$d_{88} = 0.000$

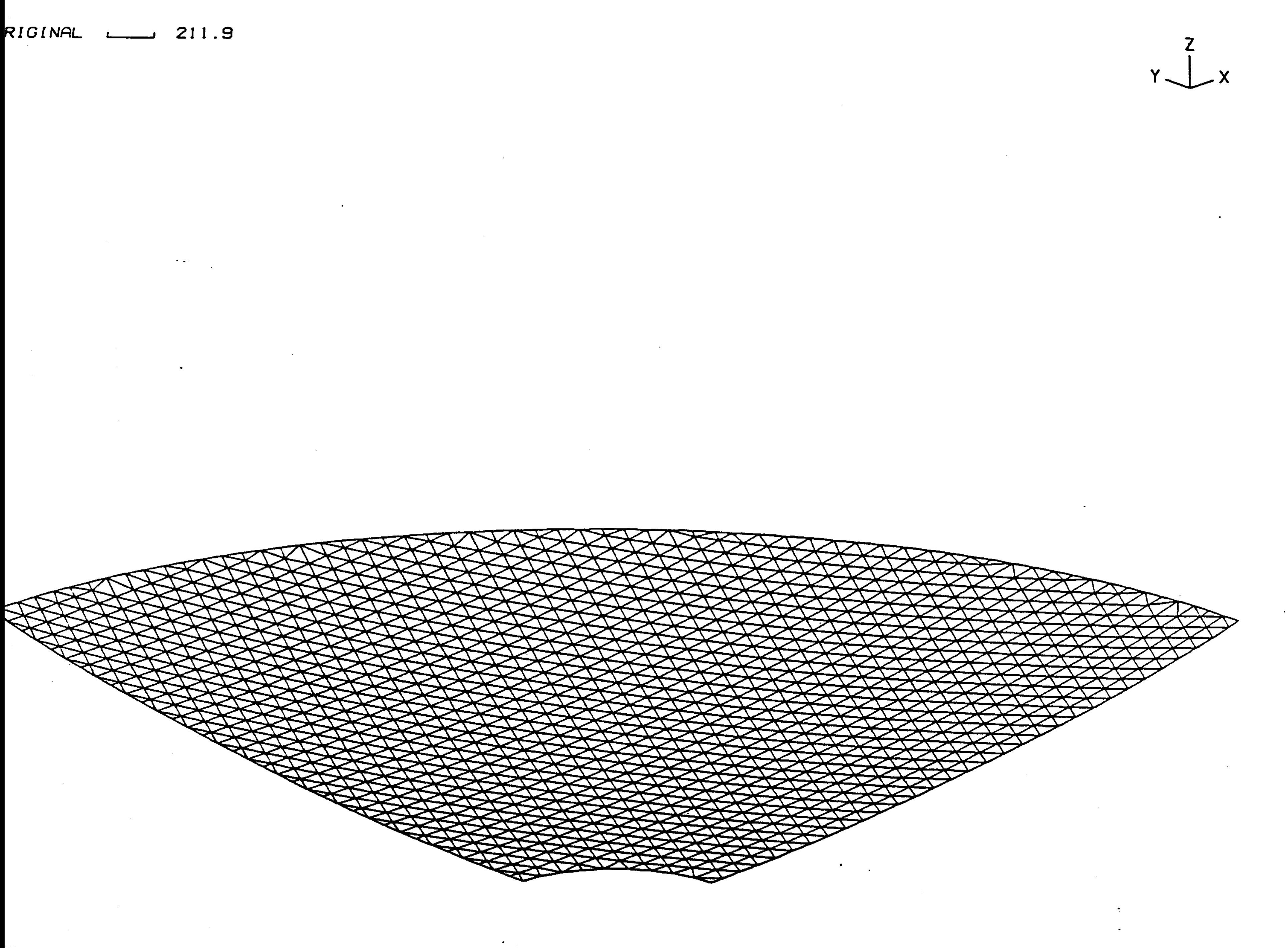
Practically only the polynomial $c_{22}\,\rho^2 \cos 2\theta$ is important.

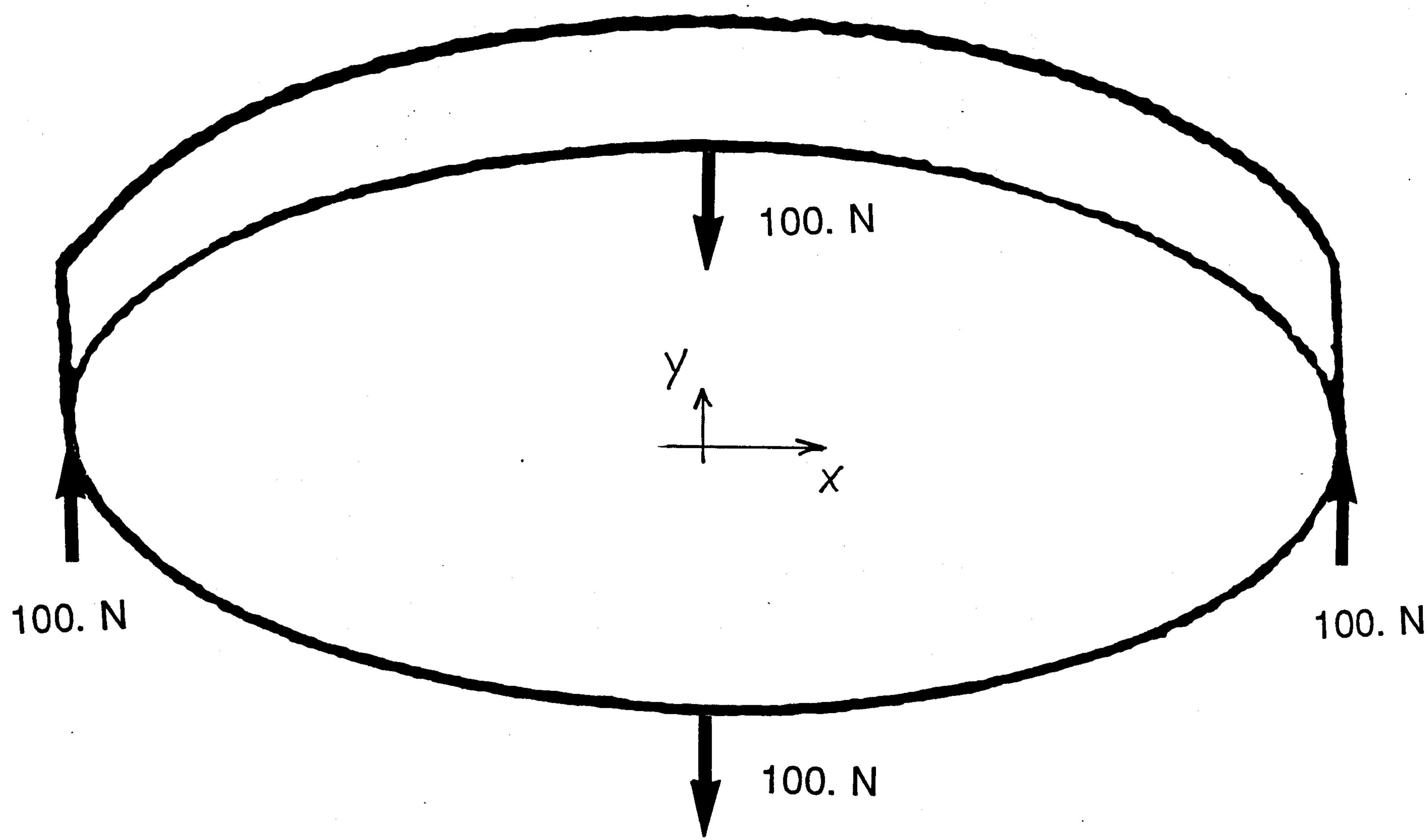
The results related to the structure function are reported in the following table:

STRUCTURE FUNCTION			
DISTANCE cell side	COUPLE NUMBER	AVERAGE VALUE (mm)	STANDARD DEVIATION (mm)
1 side	12924	$-0.88\ 10^{-5}$	$0.390\ 10^{-4}$
2 sides	12658	$-0.18\ 10^{-4}$	$0.778\ 10^{-4}$
4 sides	12254	$-0.38\ 10^{-4}$	$0.154\ 10^{-3}$
8 sides	11358	$-0.85\ 10^{-4}$	$0.302\ 10^{-3}$
16 sides	9437	$-0.19\ 10^{-3}$	$0.554\ 10^{-3}$
32 sides	6739	$-0.56\ 10^{-3}$	$0.815\ 10^{-3}$

In figure 8 is reported the Structure Function "distance - standard deviation".

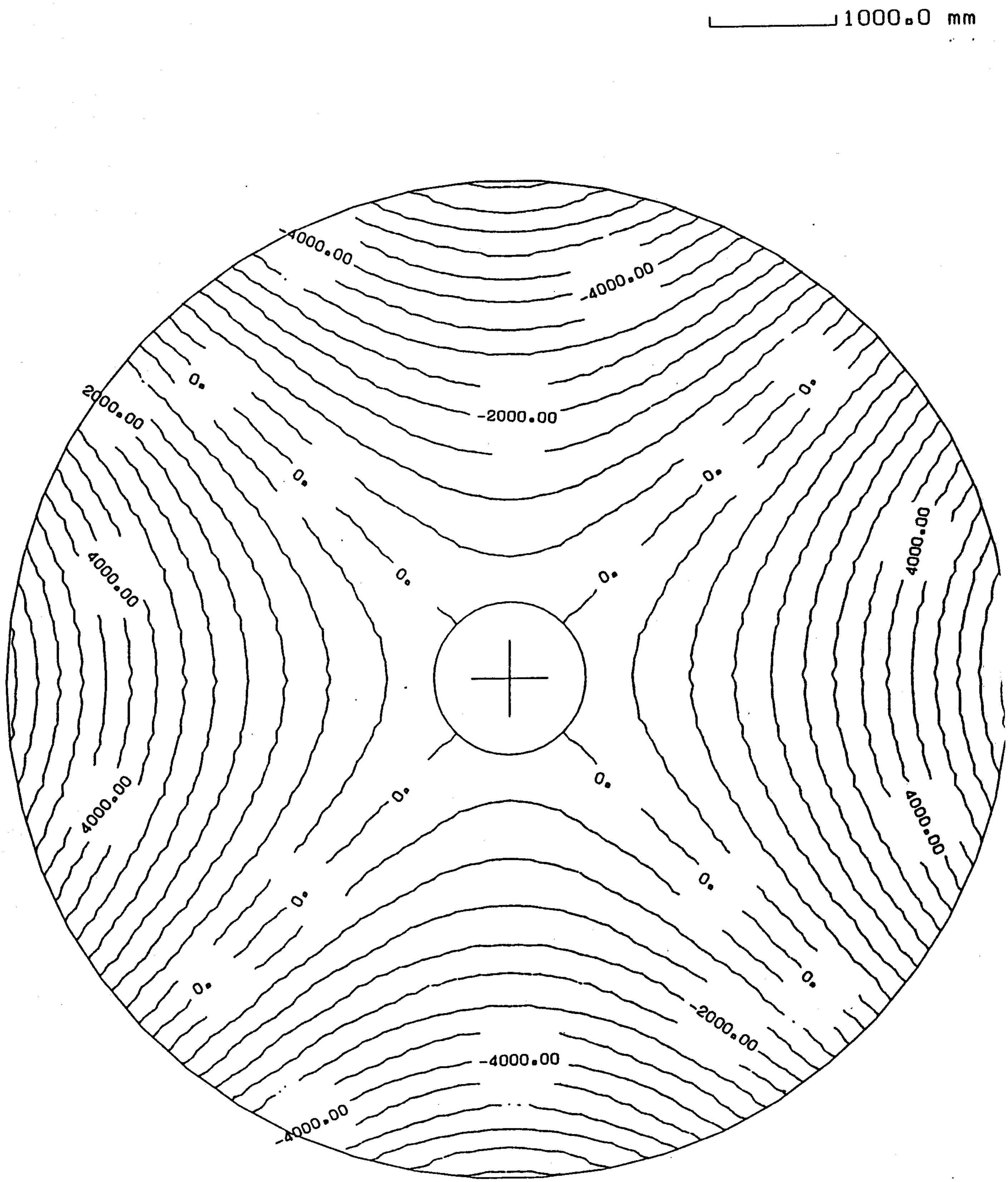
In figure 7 are plotted the areas around the focus related to an assigned percentage of the total energy; such areas have been plotted for the pergentages from 10.% to 100.% step 10.%. From this figure we obtain that the 90. % of the total energy is included in a "cone" having 0.50 arcsec angle.


RIGINAL
211.9
Z
Y
X



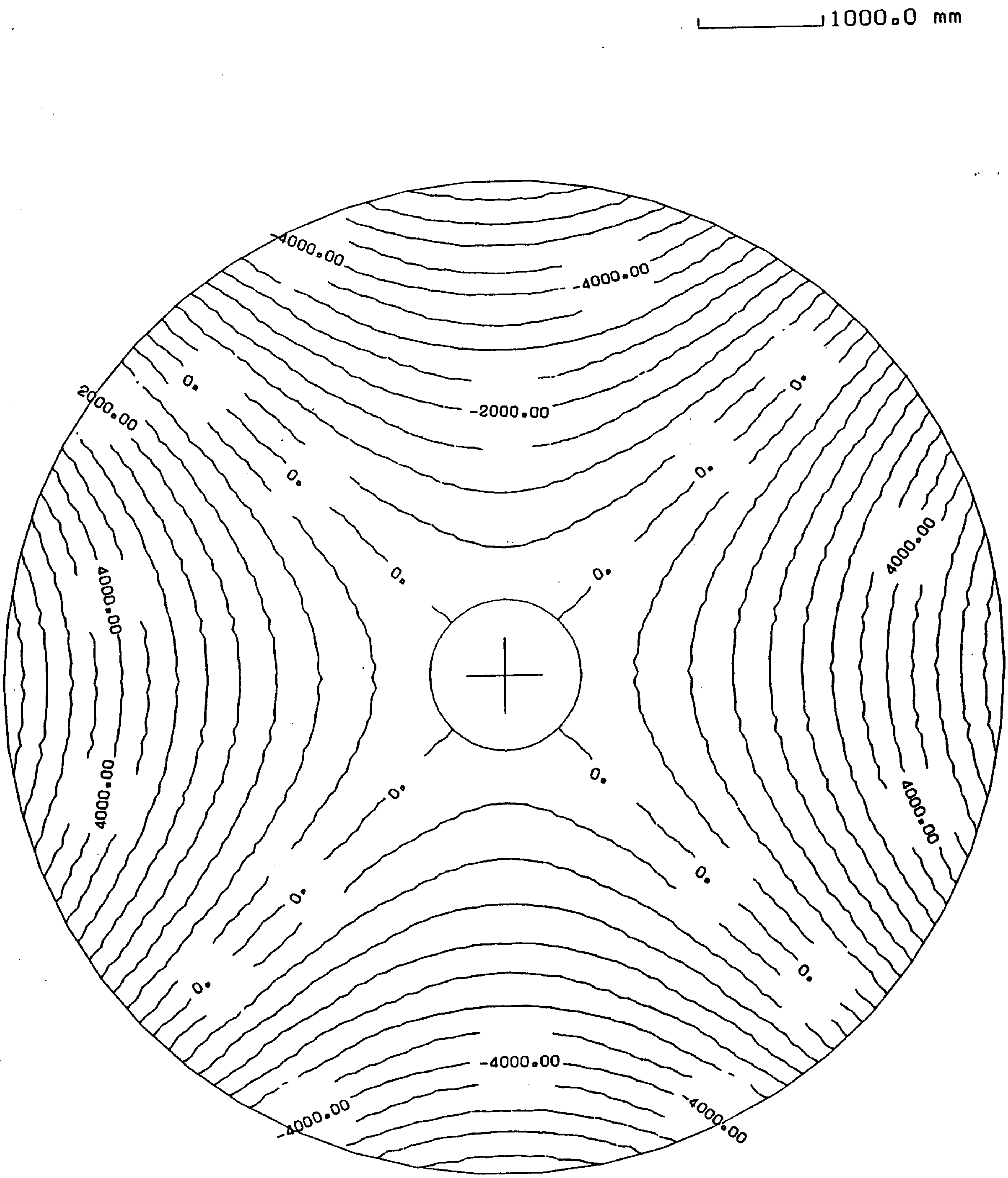
100. N
y
x
100. N
100. N
100. N

meniscus f.e. analysis



ISOCONTOUR STEP = 500 nm

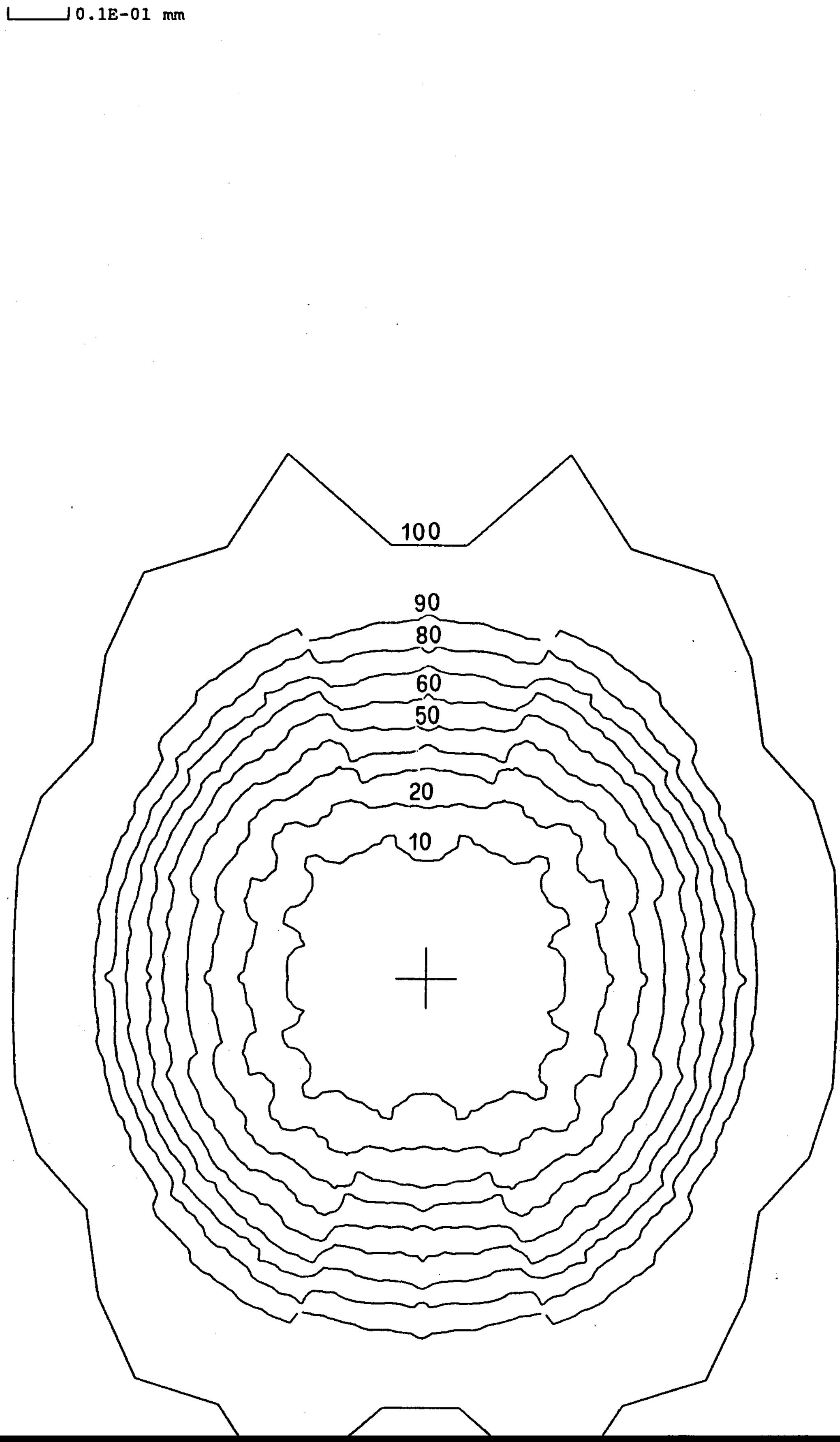
meniscus analyt. form.



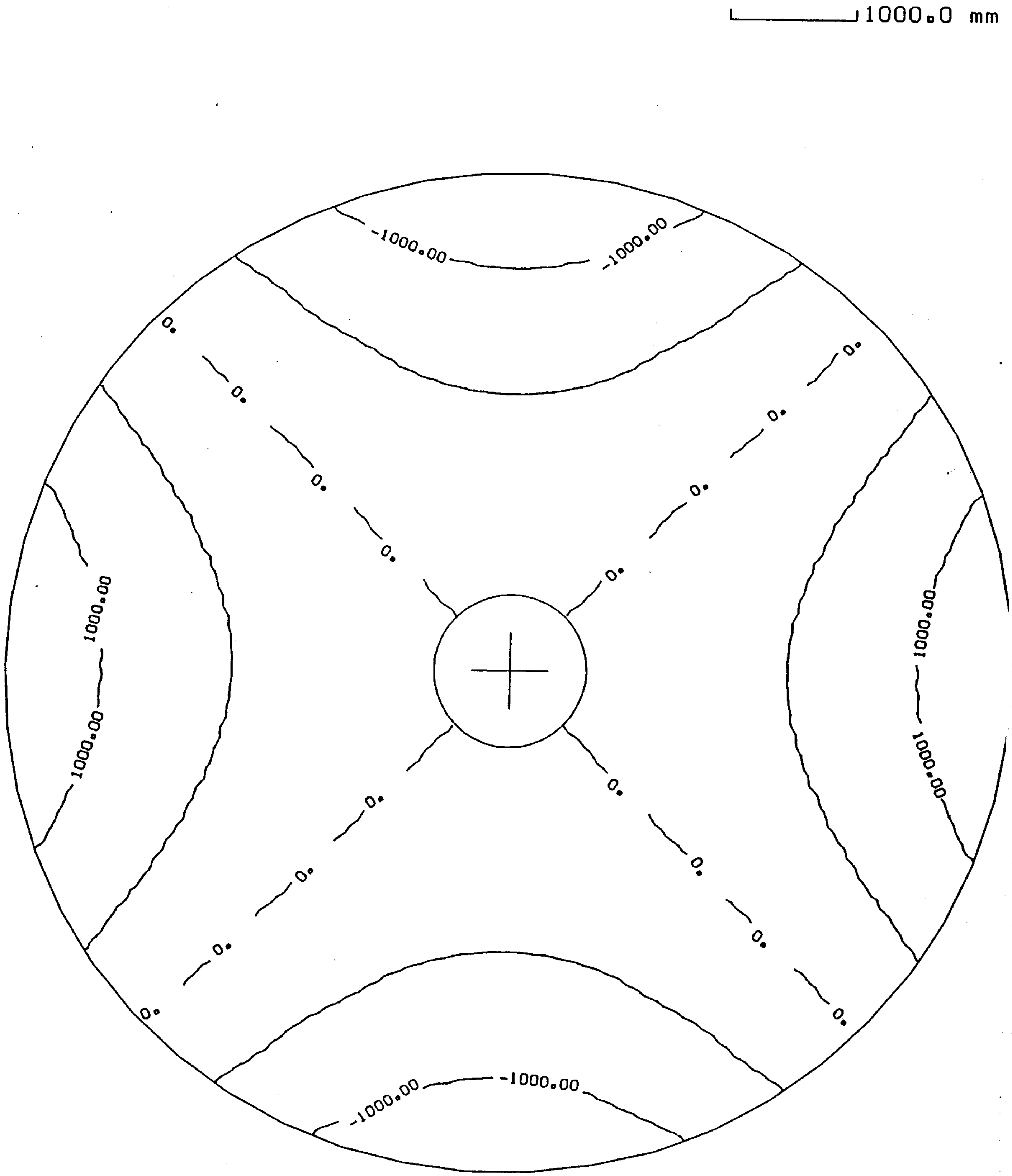
ISOCONTOUR STEP = 500 nm

MENISCUS - ENERGY PERCENTAGE

0.1E-01 mm



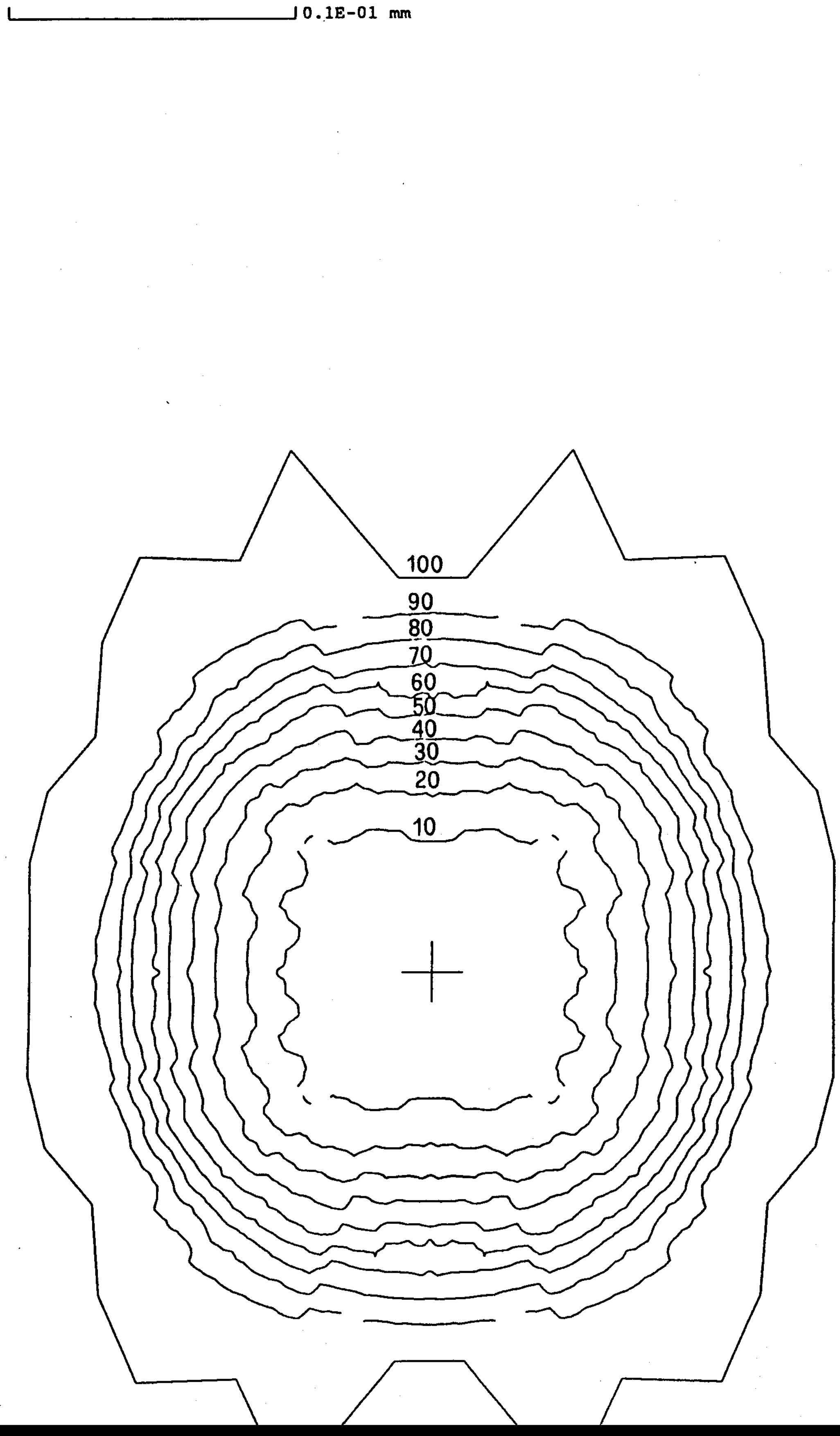
honeycomb mirror

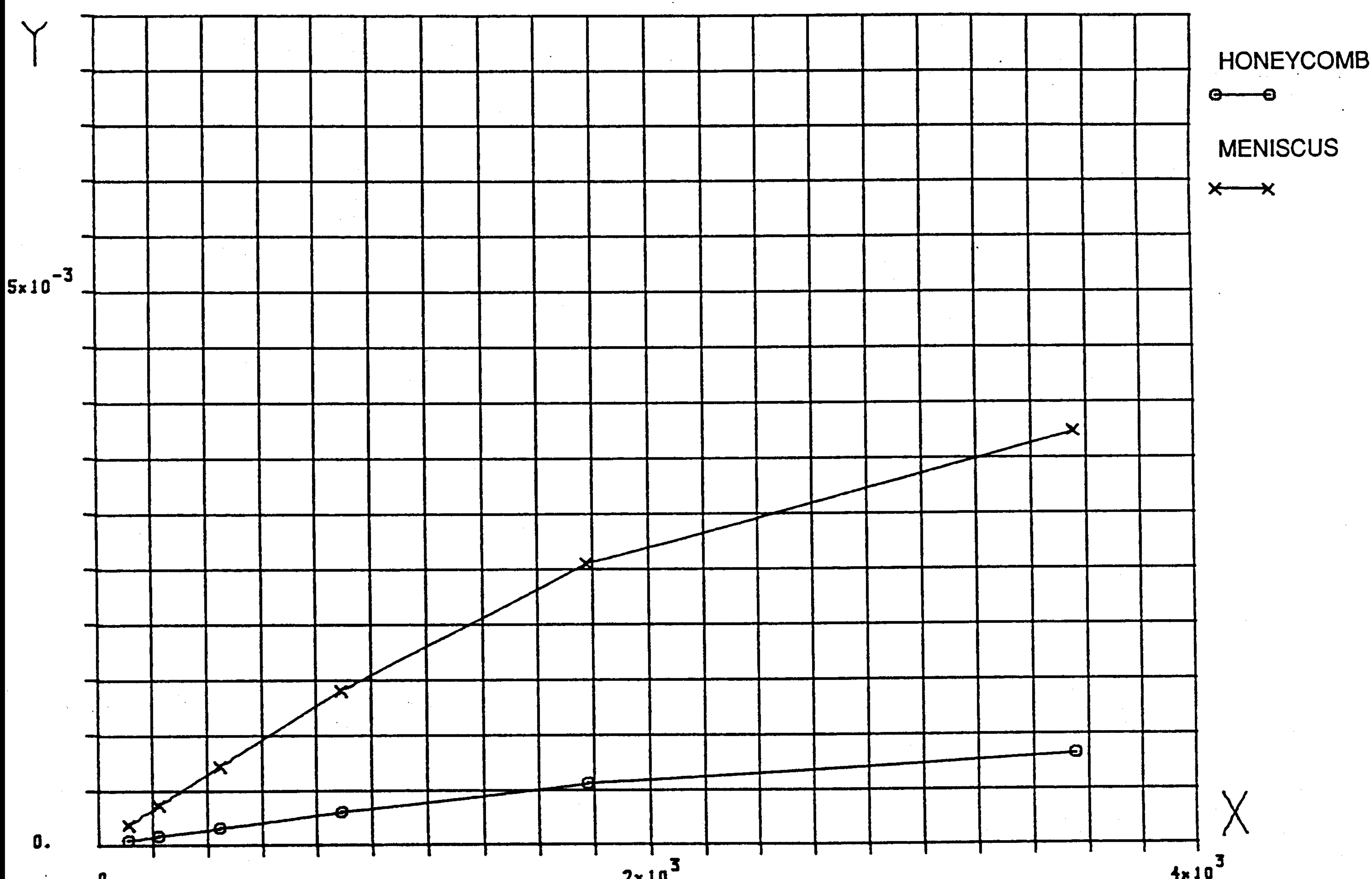


ISOCONTOUR STEP = 500 nm

HONEYCOMB - ENERGY PERCENTAGE

0.1E-01 mm





X = DISTANCE (mm)

Y = STRUCTURE FUNCTION (mm)