EXACT SOLUTION FOR CHERNIN FOUR OBJECTIVE MULTIPASS CELL

A.G.Berezin, S.M.Chernin
Natural Sciences Center of General Physics Institute named by A.M.Prokhorov of Russian Academy of Sciences, 119991, Vavilov Str. 38-L2, Moscow, Russia, e-mail anber@nsc.gpi.ru

The properties of Chernin four objective matrix multipass cell [1] were investigated experimentally and theoretically, on a base of model calculations. Chernin multipass cell consists of two blocks of mirrors, one of which has four objective mirrors and the other two field mirrors. System works as consequence of Barskaya [2] optical schemes, initially forming two lines of images on field mirror with a help of one pair of objectives. Contrary to Barskaya scheme the final image of line is not send to detector but hits auxiliary field mirror and returns into the cell falling on one of objectives from another pair and two new lines of images appear on main field mirror. Working in turn, objectives form a matrix of images on field mirrors.

An exact solution for beam propagation based on the rules of geometric optics was found and program was written that could calculate position, incoming and outcoming angles on corresponding mirror at every pass. Main attention was paid to the system stability. The critical parameters to which an alignment was most sensitive were determined and it was found that positions and declinations of objective mirrors with respect to each other were most critical, while the distance between two blocks and their tilting as a whole were less critical.

Theoretically the number of passes in Chernin multipass cell is not limited. Practically optimal number of passes depends on mirrors' reflectivity and aberrations. This work was dedicated also to find out the limitations arising due to aberrations. It was found that aberrations in ideal Chernin optical cell should be mostly compensated during beam propagation and final spot at the exit of a cell should be much smaller than intermediate spots. Experimentally, although, aberrations were much larger and they increased with number of passes.

[1] S.M.Chernin, E.G.Barskaya, Appl.Opt. 30 (1991) 51.

[2] E.G.Barskaya, 1968, USSR Invention Brevet 206857.

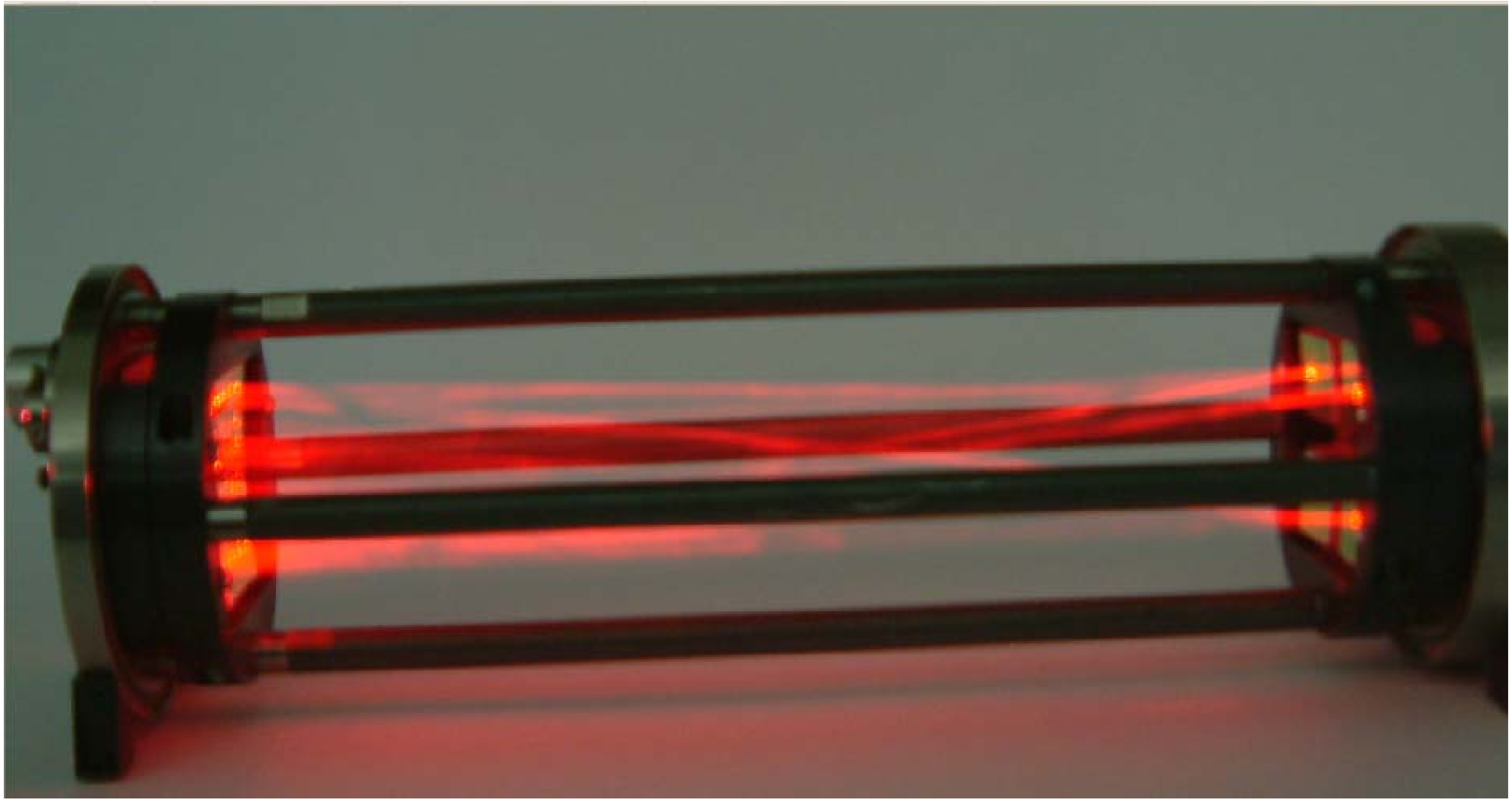
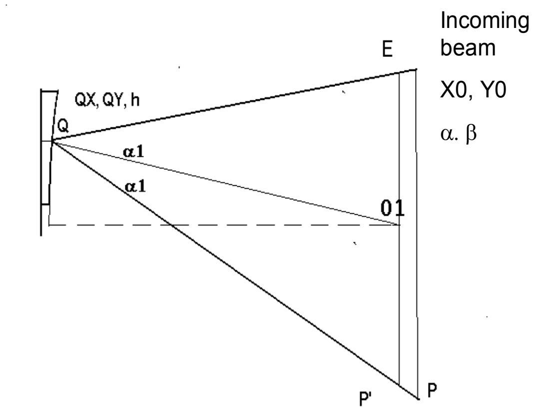
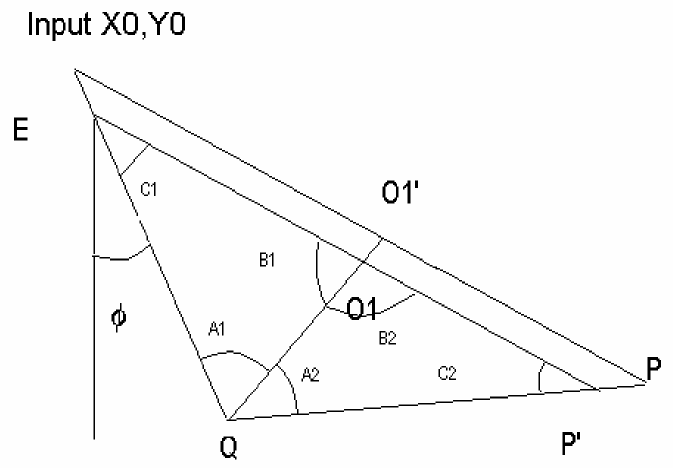


Fig. 1 View of Chernin matrix multipass cell, 25 cm base length, 156 passes.

Falling of incoming beam on first objective



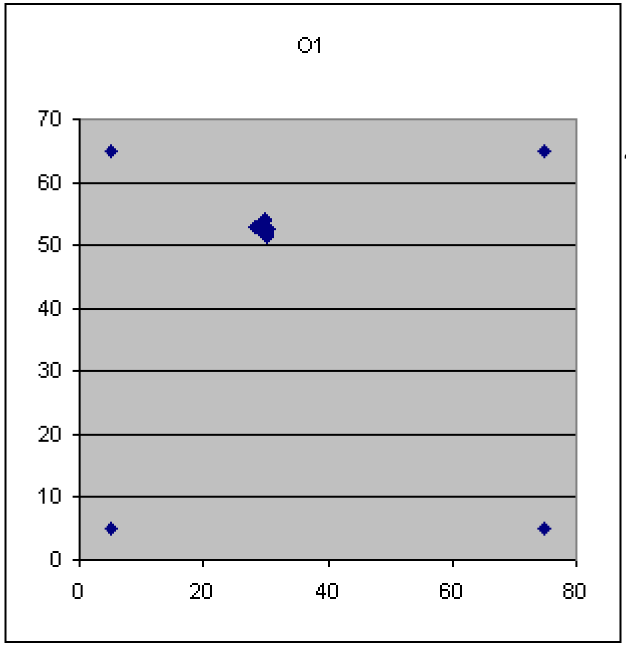


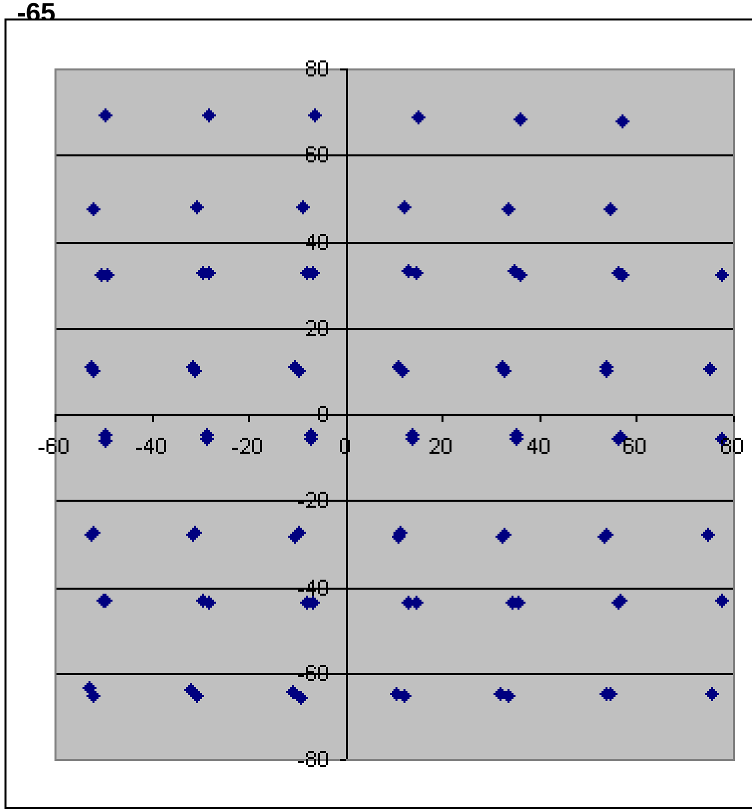
Details of calculation: position of incoming beam on spherical mirror was calculated using stereometric task solution, using projection of a beam reflection on a base X-Y plane. Position of a beam on mirror surface was found as mutual solution for a given sphere surface equation and linear X-Y projection on base surface equation.

Front panel of calculation program

Shiftinput x		12	3	Centers of mirrors			X	Y			Shift X	Shift Y	
Shift input y		8	3	Main field mirror			0	0		1.3	2	-7	
Input x0		77	21	Auxiliary field mirror			37.5	0				0	
R3, auxiliary		1200	18						Изм. X	Изм. Y			
Input y0		67	24	**1-st objective**			**12.625**	**2.302857**	0	0.16	77.56002		
R1, main		1200	18	**2-nd objective**			**2**	**2.302857**	0	0.16	-43.2034		
R2 objectives		1208	21	**3-rd objective**			**12.625**	**-16.1429**	0	0	0.75		
d3		1.5	24	**4-th objecctive**			**2**	**-16.1429**	0	0			
d1		0	24										
d2		0.00	24	**Mirror sizes**		**Q=**	**130**	**P=**	150				
α, plain deviation		-0.035	**75.23787**	Main field mirror					center	Left up	Left down	Right up	Right down
β, deviation in plane		-0.02	**47.47834**	**1**		**21.25**	**-65**	**75**	-0.049	-0.031	-0.06	-0.01	-0.032
				3		**18.28571**	**65**	**75**	-0.005	-0.038	-0.0064	-0.006	0.012
				3			**-65**	**-75**					
QREAL		30.0149377	54.31478	**4**			**65**	**-75**		1	-0.0627	-0.0205	
1-ая точка на полевом зеркале				Auxiliary field mirror		**c=**	**30**	**d=**	30	2	-0.049	-0.026	
PREAL		- 52.8238361	-63.3917	**1**			**65**	**40**		3	-0.035	-0.02	
				2			**90**	**40**		4	-0.029	-0.006	
18	42.75	25		**3**			**65**	**-75**		5	-0.035	0.008	
30.22881	12.72792	12.7279221		**4**			**90**	**-75**		6	-0.0493	0.013	
17.67767	5.228815	30.2288149								7	-0.0632	0.0072	
	12.72792	47.9064844		**1-st objective**	**distance X=**	**10**	**distanceY=**	**10**		8	-0.069	-0.0067	
	30.22881	55.2288149			**sixe X=**	**70**	**sizeY=**	**60**					
	47.90648	47.9064844		**1**			**5**	**65**	40				
	55.22881	30.2288149		**2**			**75**	**65**					
	47.90648	12.5511454		**3**			**5**	**5**					
	30.22881	5.2288149		**4**			**75**	**5**					
	30.01494	54.3147819		**2-nd objective**									
				1			**-5**	**-5**					
				2			**-75**	**-5**					

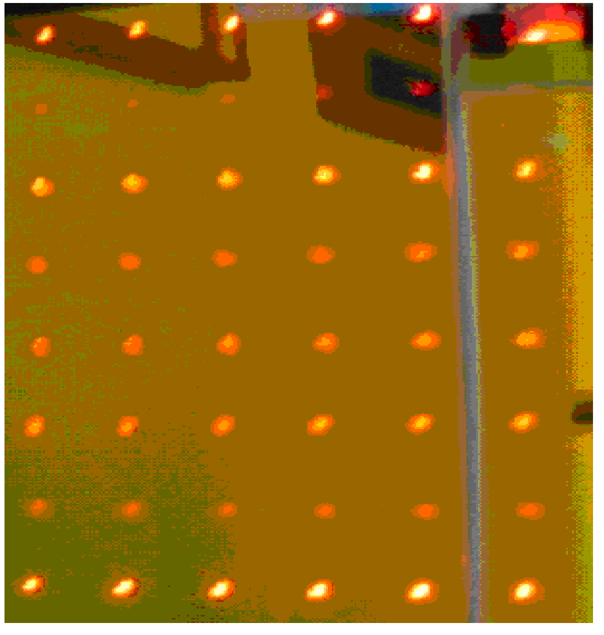
30.01494	54.3147819	3	-5	-65
		4	-75	-65
	-			
77.56002	43.2033857	3-rd objective		
		1	75	
		2	5	
		3	75	
		4	5	
		4-th objecctive		
		1	-75	
		2	-5	
		3	-75	
		4	-5	

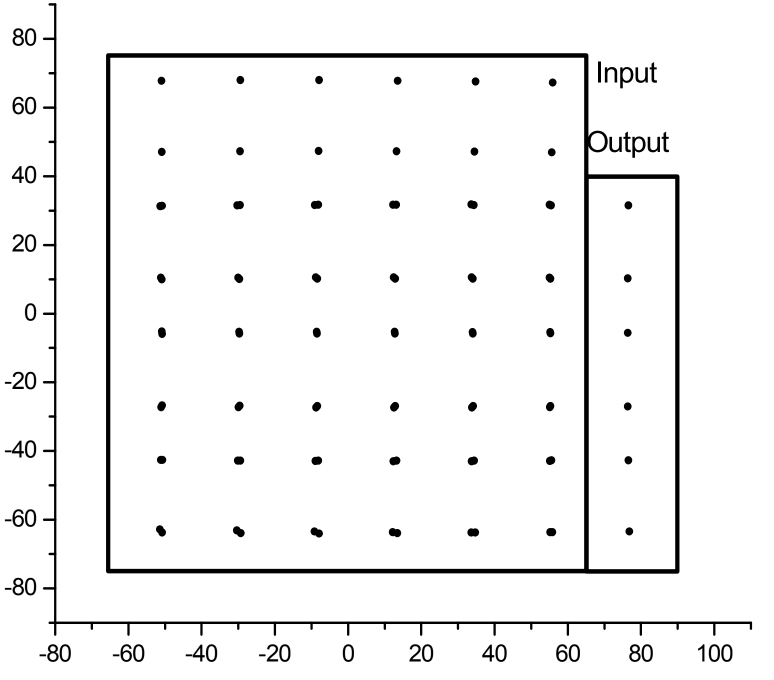




The following parameters could be set as initials into the program: curvature and position and declination of each of six mirrors separately; each mirror sizes; position and angles of incoming beam. Left insertion shows schematically edges of first objective and sequence of spots. Right insertion shows pattern of images on field mirrors.

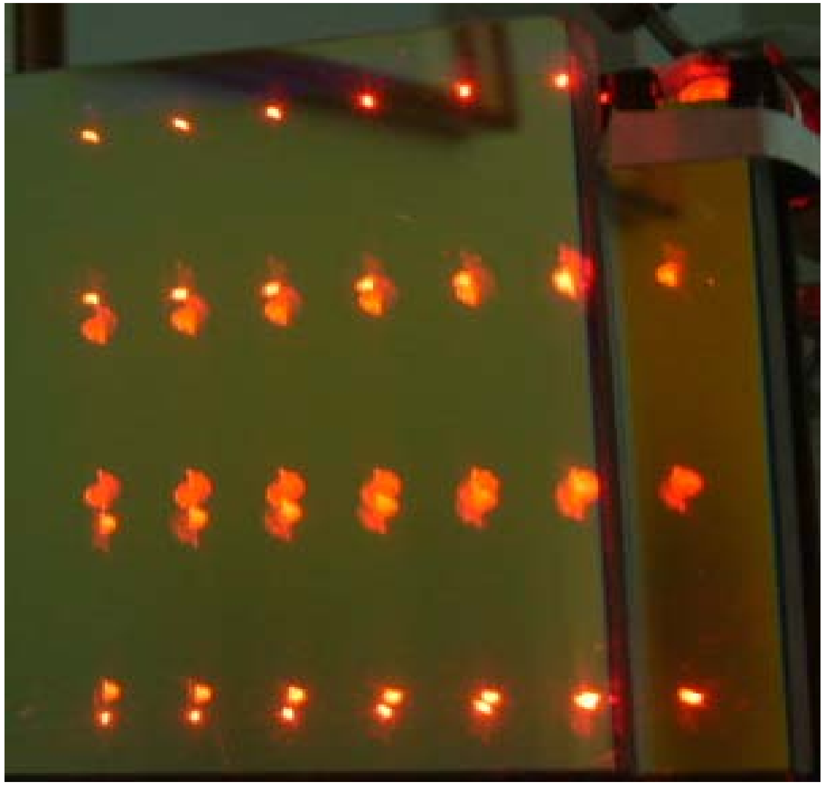
A view of matrix of images on field mirrors (ideal case)

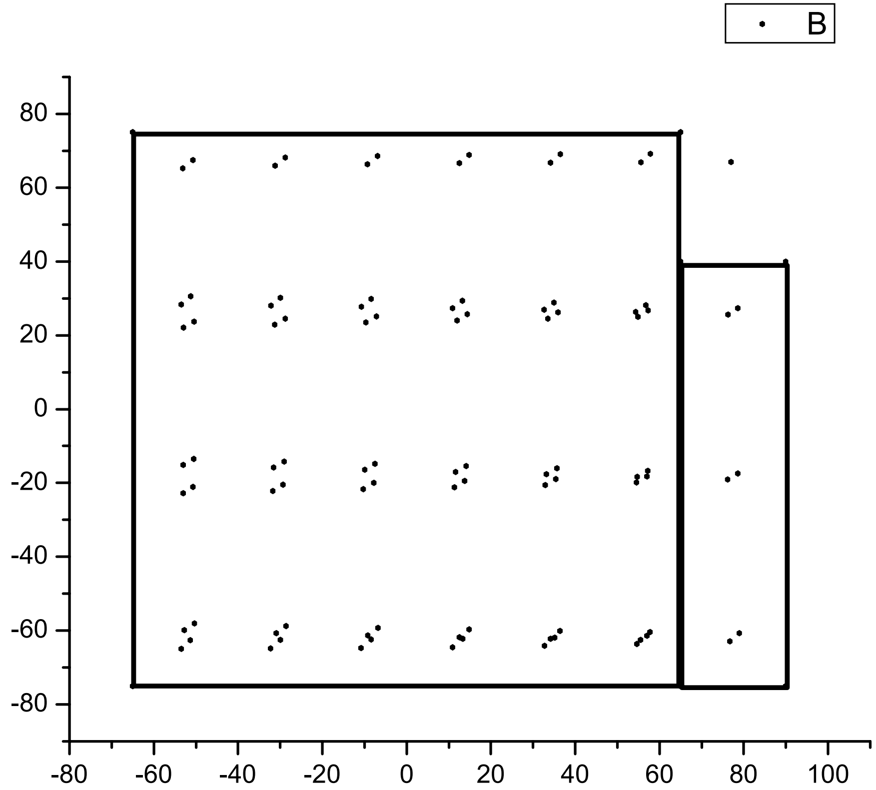




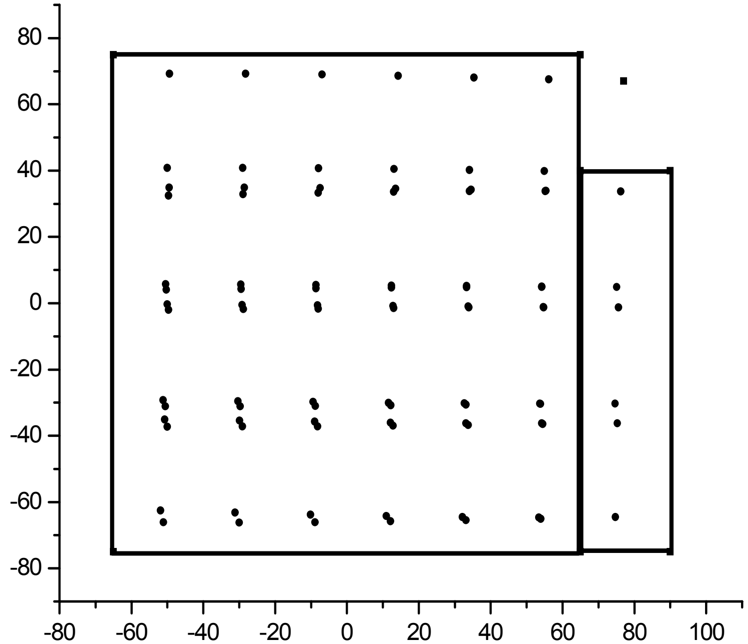
Experimental and calculated pattern of images on fields mirrors for the cell with 1200 mm mirrors curvature. The picture was obtained with parallel beam of He-Ne laser. As could be seen, pairs of images in ideal matrix do not fully coincide – this is due to final distance between two sets mirrors. The same effect leads to aberrations.

Experimental and calculated matrix of images on field mirrors (two sets of mirrors were shifted towards each other by 3.8 mm)



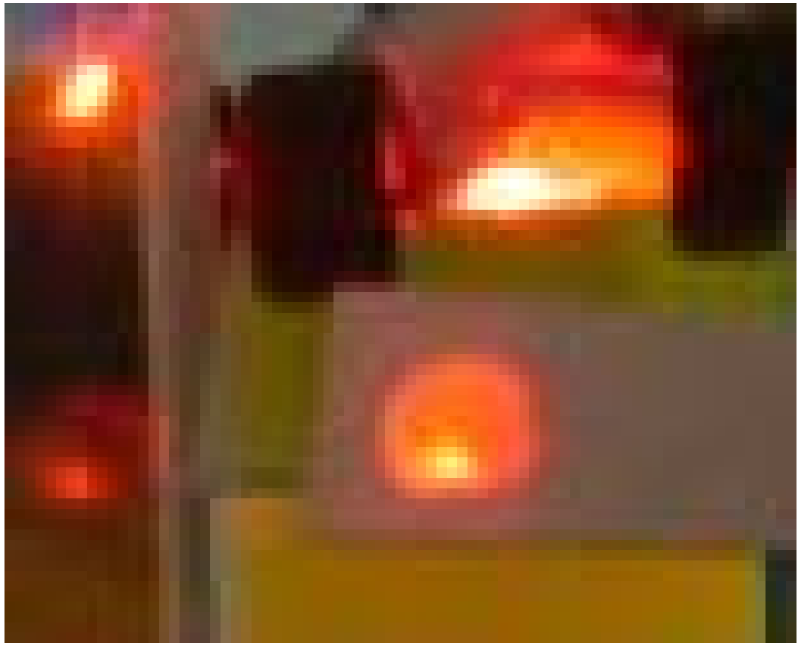


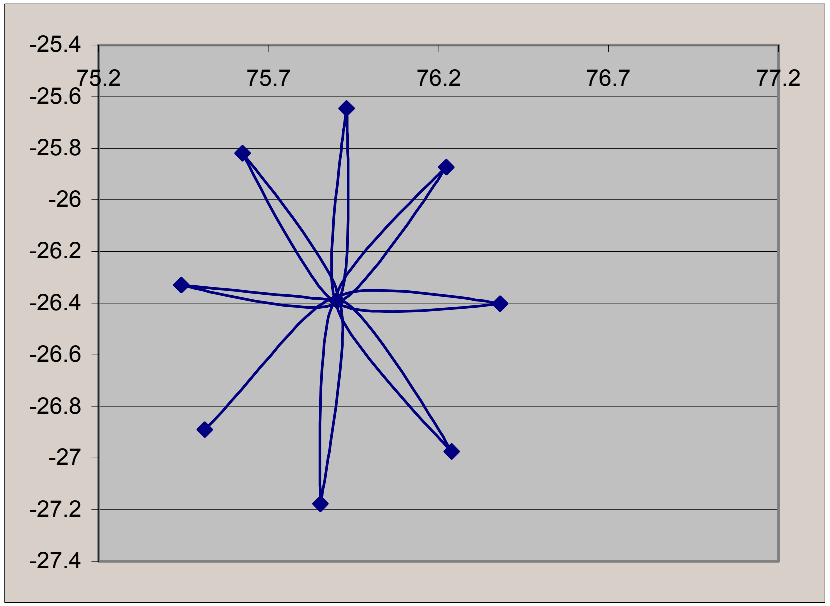
Experimental and calculated matrix of images on field mirrors (two sets of mirrors were separated from ideal position by 2.8 mm)



There is good agreement between experimentally observed and calculated patterns of images.

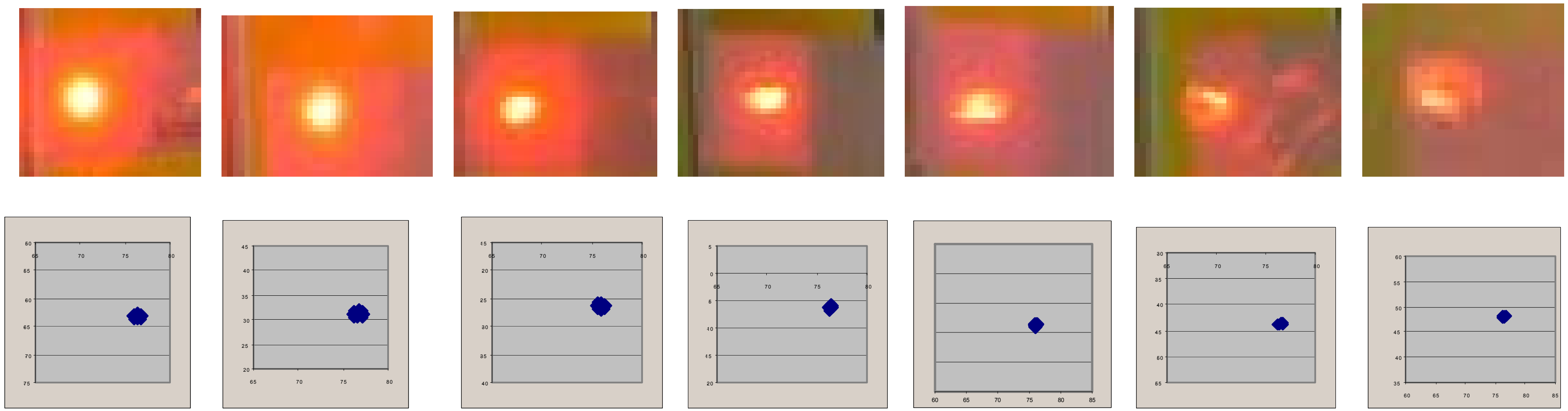
As aberrations at the system output were calculated





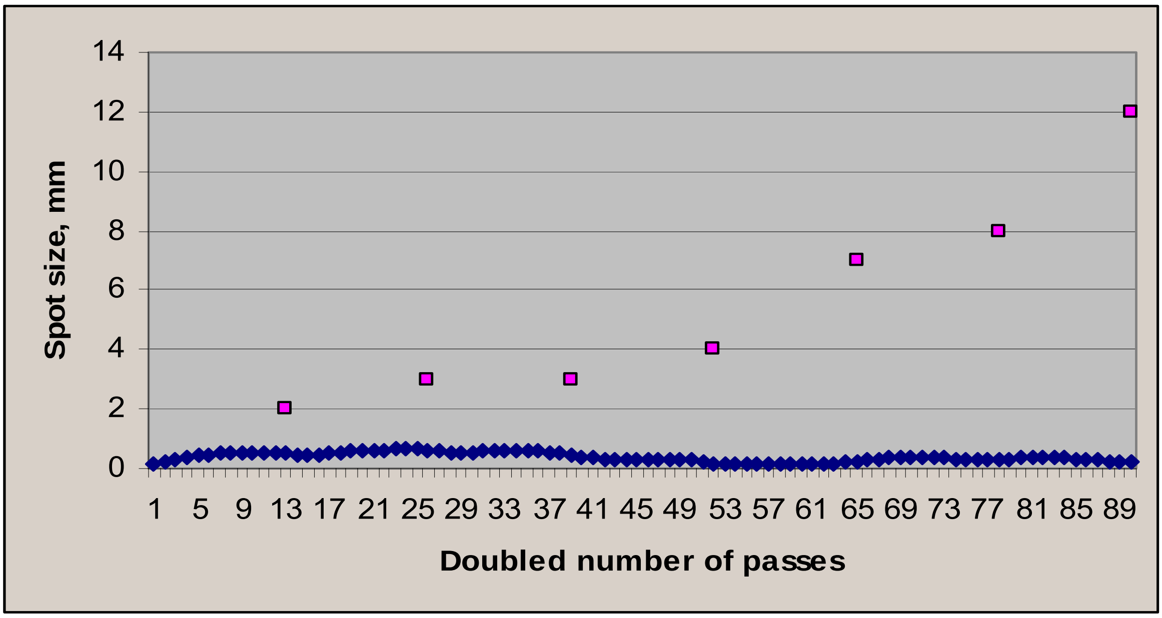
Aberrations were calculated as a middle distance between center and peripherical aberration spot frame. Minimal experimentally observed output aberration was 8 mm.

Experimentally observed and calculated aberration spots on auxiliary field mirror



Photographs of aberrations spots on auxiliary field mirror were compared with calculated ones. Unlike positions of the spots on field mirrors, there is poor agreement between calculations and experiment.

Dependence of experimentally observed averaged size of aberration spots on auxiliary field mirror and calculated dependence of aberration spot size vs number of passes



Experimentally observed averaged size (pink squares) of aberration spots are much larger than theoretically predicted (lower curve). That could be due poor quality of mirrors.