Multiview Autostereoscopic Display Technology and Applications

Sung Sik Kim, Sergei A. Shestak
Samsung Electronics, Suwon, Korea

Abstract

Optical architecture and experimental results on low cost multiview autostereoscopic projection display are presented. The display, containing only one high resolution projection panel and only one projection lens is capable of displaying multiview autostereoscopic images. Key components, applied in the display are segmented mirror for splitting the projection beam and one-dimensional diffuser with slanted axis of diffusion for viewing zone formation. Image distortions, inherent in the display have been compensated with opposite sign pre-distortion of projected perspective images.

Key words: multiview autostereoscopic projection, single lens, tilted diffuser, image distortion.

1. Introduction

We present optical architecture and experimental results for inexpensive multiview autostereoscopic projection display, which employs only one *high resolution* projection panel and only one projection lens to provide multiview image with *lower resolution.* The main merits of such displays are comparatively low cost, standard 2D interface, flexible design, allowing usage of commercially available and mass production components.

Principle of the optical design is similar to some old stile stereoscopic attachments applied long ago for stereoscopic cinema-projection. The attachment had mirrored prism or mirror assembly to dissect the projection beam on two parts and then to converge both parts upon the screen[1,2]. Also the same principle of operation is employed in another very simple stereoscopic attachment, comprising just bi-mirror, set at 45 degrees to the projection axis[2]. The below described concept allows further simplification and cost reduction of projection type multiview autostereoscopic display.

2. Optical setup

The attempt of extension the design principle of simple stereoscopic attachment to the multistereoscopic projection has been long described[3]. Now we found another way of such extension that is more simple and convenient especially for wide-angle projection system. Optical setup of 4-views autostereoscopic display is shown in Fig.1. Image projector 1 projects four perspective images, arranged on the projection panel 2 in two rows and two columns, as it is shown in the picture. The projection beam from the image projector hits segmented mirror 3, which splits the beam at four partial beams. Each mirror reflects mostly the light, coming from one perspective image and it is aligned so, that all perspective views appear convergent upon the screen 4.

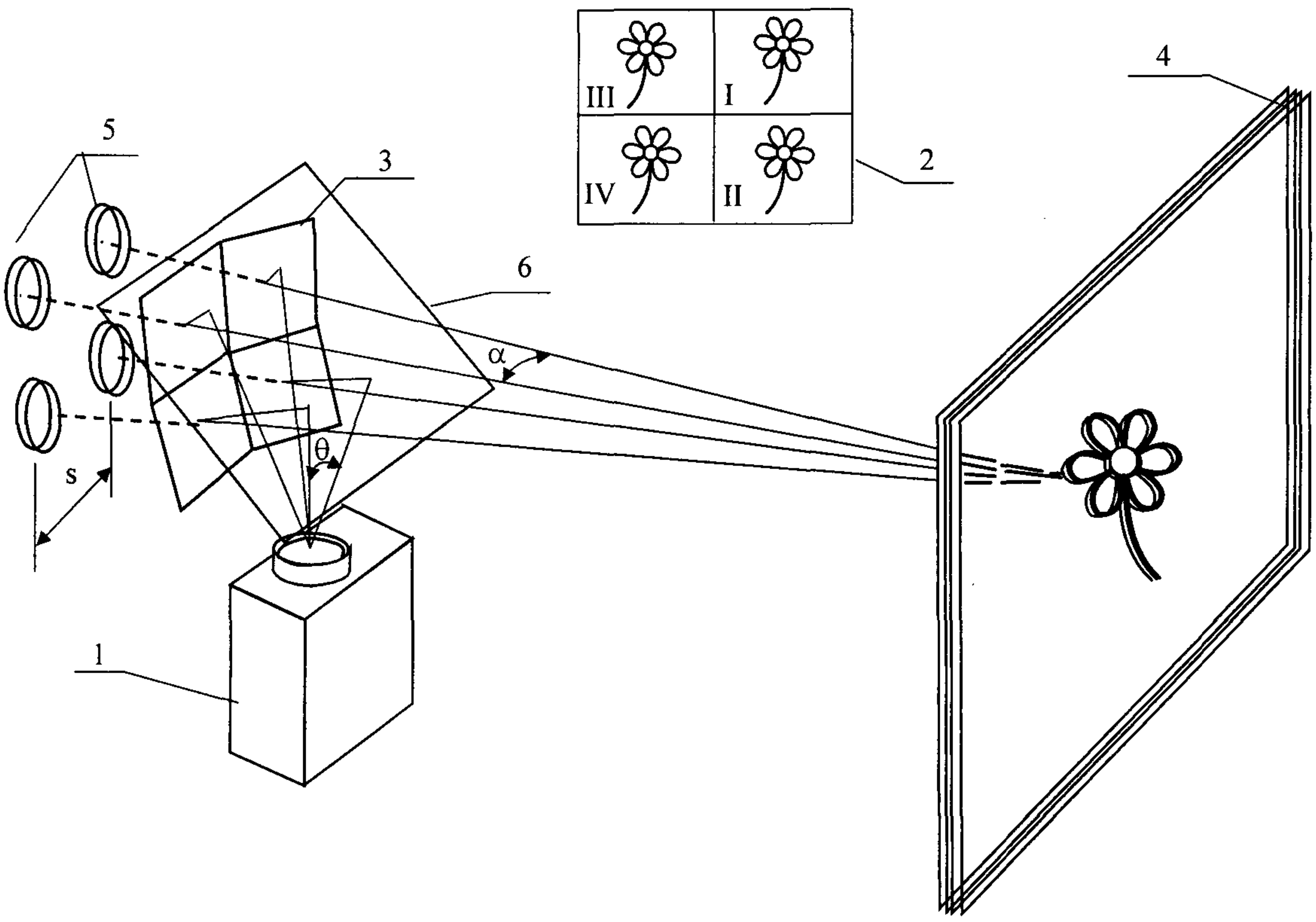

Fig.1 4-views autostereoscopic setup

Being declined at certain angle in respect to the projection axis, each mirror produces separate virtual image of the projection lens 5. Four virtual openings of the image projector appear arranged in 2 rows. As a result just one image projector works as 2-D array of projectors, each of which projects only one perspective image. Imaging screen is composed of Fresnel lens and one-dimensional diffuser. In order to prevent rotation of the converged images, use of semitransparent mirror 6 provides normal incidence of the beam to the segmented mirror.

In order to transform two rows arrangement of the virtual openings in to horizontal distribution of four viewing zones we propose specific orientation of one-dimensional diffuser, which conventionally diffuse light in vertical direction. As it is shown in Fig.2, the diffuser, which axis of light spreading is tilt in respect to the vertical direction, spreads the light in the viewing zones so, that certain area with horizontally distributed viewing zones appears. The fact that viewing zones appear slanted doesn't create any problems in viewing. The tilt angle φ between the diffuse axis and the vertical can be chosen depending on number of the projectors openings and their arrangement. If the projectors openings are arranged in m rows and n columns, to create m×n viewing zones, evenly distributed in horizontal direction, the axis of diffusion should be tilt at the angle φ :

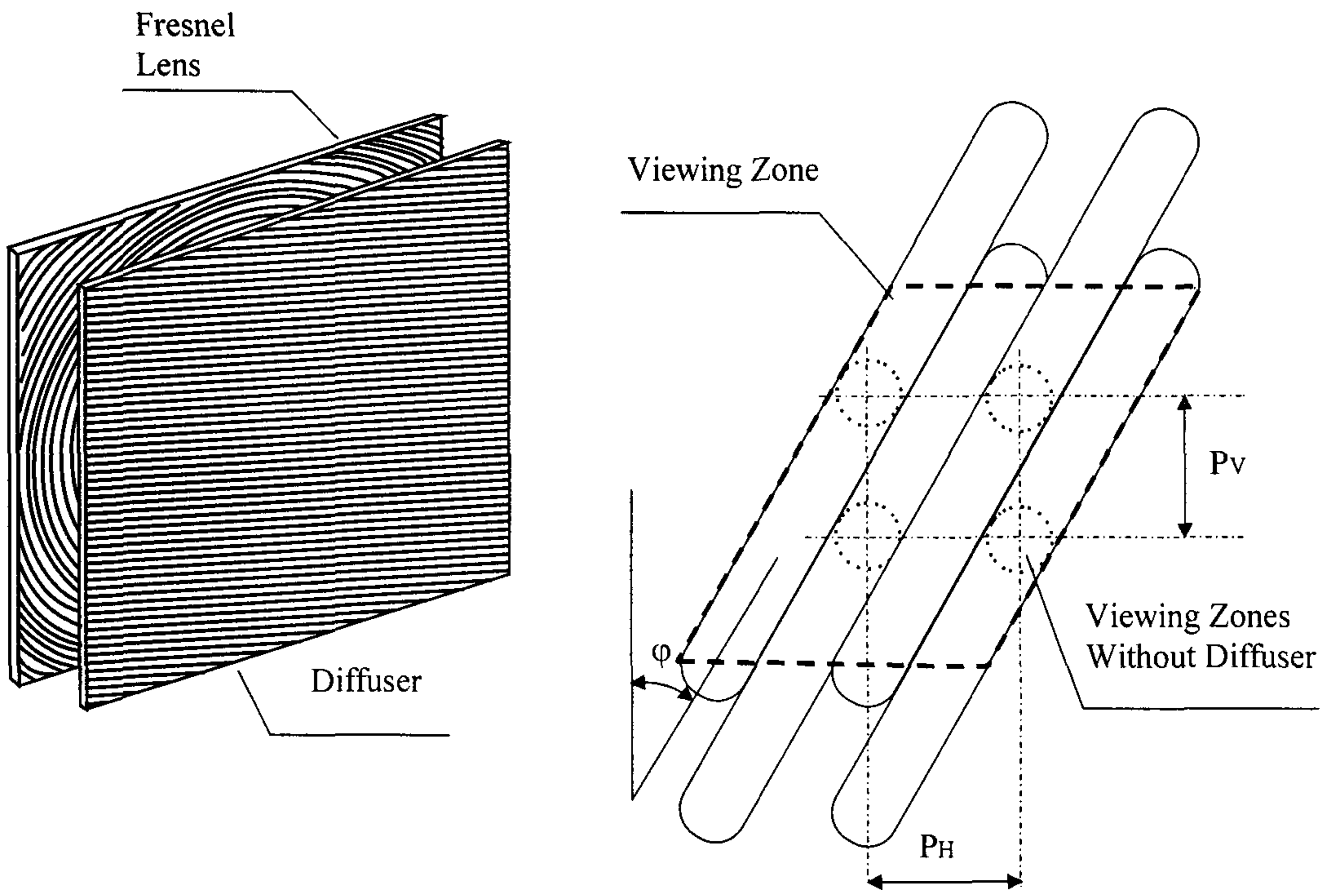

Fig.2 Screen structure and viewing zone formation.

$$\varphi = \arctan[(P_h/P_v)/m] ;$$

where P_h and P_v are the distance between the openings in horizontal direction and in vertical direction correspondingly.

In the simplest case P_h/P_v is equal to the aspect ratio of the projection panel. For instance in Fig.1 openings are arranged in two columns and two rows one above the other and the horizontal and vertical separations between the openings are in the ratio 4:3. To create 4 evenly distributed viewing zones, the tilt angle φ should be 33.7 degrees.

The important design parameter - separation between virtual openings **s** can be calculated from the following equation:

$$2\mathbf{l}(1/\mathbf{s} + 2/\mathbf{W}) = 1/\tan(\theta/2) ;$$

where **W**/2-the desirable image size, Θ-angle of projection, **l**- optical distance between projection lens and segmented mirror.

Conventional projection lens provides well focused and undistorted image only if the projection beam is unchanged. If the image is separated on parts and each corresponding component of the projection beam is declined to the center of the screen as in present display, partial images experience defocusing and unequal distortion. Image defocusing could be not so critical if the effective size of the lens opening is small enough. As for the distortion, unfortunately it is not confined to the conventional keystoning, which occurs in multi-projector autostereoscopic systems. The conventional keystone distortion is roughly proportional to the angle of convergence α. Unlike the conventional case in the present display the distortion is proportional to the sum of two angles: angle of convergence α and projection angle θ. While the value of α is in the order of several degrees, θ can be as great as 90 degrees in wide-angle image projectors. This fact dramatically increases distortion. The distortion of images leads to noticeable vertical disparity in the displayed perspective images. Fig. 3 shows how the distortion of rectangular object changes vs. the position of the perspective image on the projection panel. In order to provide high fidelity stereoscopic sensation proper pre-distortion of perspective images should be applied.

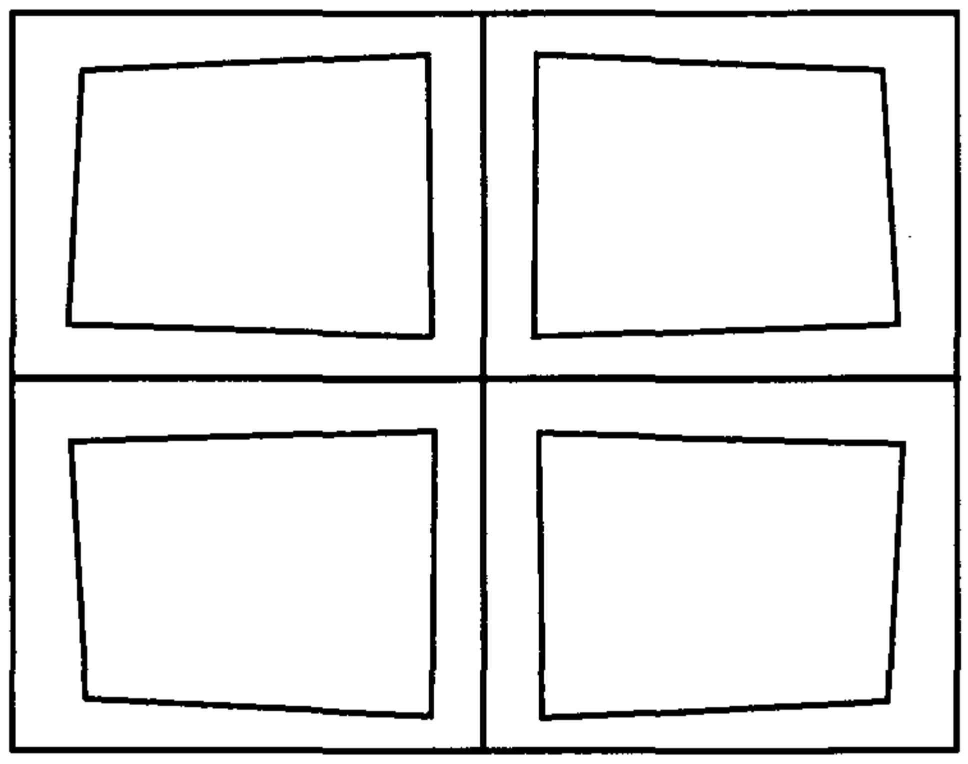

Fig.3 Distortion of rectangular object in different perspective images.

3. Experimental modeling

For experimental modeling of 4-view projection autostereoscopic display XGA LCD projector Samsung SyncMaster NX-2600 has been applied. Horizontal projection angle θ was equal to 30 angular degrees. Horizontal separation between the virtual openings s has been chosen as 112 mm, image size 400 x 300 mm^2 (20"), l= 251 mm. Projection distance-1400mm, Viewing distance 1400mm. Screen was composed of Fresnel lens with focal distance 70 cm and polygraphic lenticular sheet with the lens density 150 lpi, slanted at 34 degrees to the horizontal. Resolution of 3D image 512 x 384 pix. Another display with almost the same parameters has been built using OHP with 13,3 " LCD panel instead of image projector as an example of inexpensive solution.

A great role of using the image pre-distortion in the described display has been shown in the experiment. While watching an image without use of pre-distortion causes eye strain and doesn't give perfect stereoscopic sensation, pre-distorted images could be easily perceived as volumetric without any eye strain. We've found that satisfactory pre-distortion can be done just applying pincushion distortion to the entire frame with four perspective images.

The fact, that partial viewing zones are elongated in some slanted direction, doesn't cause noticeable problems in watching the displayed images.

Fig.4 shows an example of the displayed image.

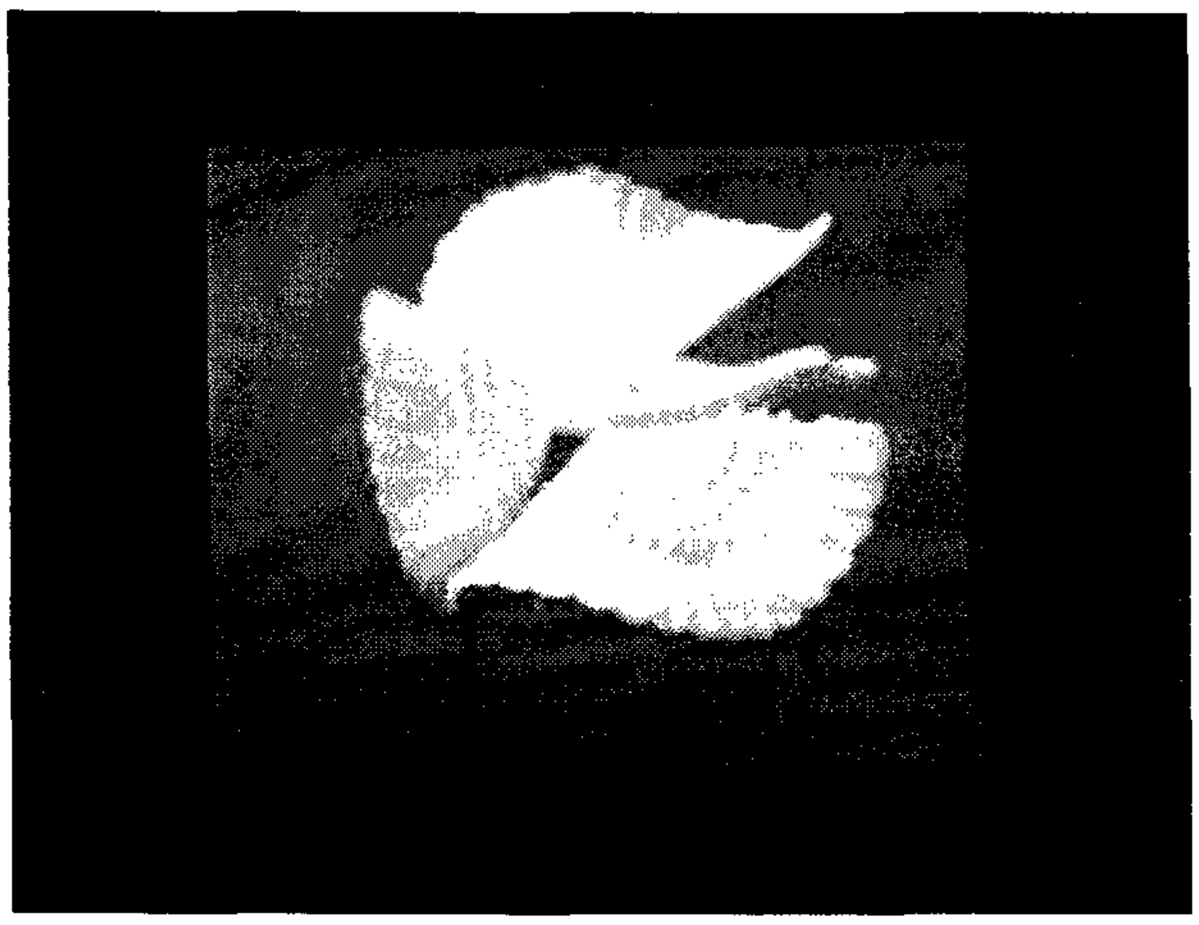

Fig.4 Example of screen image

4. Conclusion

The above described design principle includes the following new elements: usage of segmented mirror, tilting the axis of dimensional diffuser at predetermined angle, pre-distortion of perspective images to be projected. The design principle can be applied to any number of perspective views, which can be arranged in m rows and n columns. Proper pre-distortion of perspective images is critical requirement to the image data preparation. The display can be recommended as comparatively inexpensive solution for those applications, which doesn't require very high image resolution, for instance in arcade game machines.

References:

1.T.Okoshi "Three-Dimensional Imaging Techniques" , Academic Press, New York, San Francisco, London, 1976.
2.US Pat.2,314,174 D.B.Steinman "Universal stereo attachment for projectors and cameras", 1940.
3. N.A.Valius "Stereoscopy", Izdatelstvo academii nauk SSSR, Moscow, 1962.