Optimization of optical design for Eye Glass Display

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Abstract

Eye Glass Display (EGD) with microdisplay to realize the virtual display can make the large screen, so virtual image has been developed by using microdisplay panel. This paper shows study of low cost lens design and simulation for microdisplay system with 0.6" Liquid Crystal on Silicon (LCoS) panel. Lens design optimized consider to spherical aberration, astigmatism, distortion, and chromatic aberration. Code V is used and it designed an aspheric lens about exit pupil 6mm, eye relief 20mm and 35 degree of field of view (FOV). With the application this aspheric lens to LCOS type's microdisplay, virtual image showed 50 inch at 2m. One side of the aspheric lens was constituted from diffractive optical element (DOE) for the improvement in a performance. It had less than ±2% of distortion value and modulation transfer function in axial had 20% of resolution with 30 lp/mm spatial frequency. The optical system is suitable for display of 0.6"-diagonal with SVGA.

1. Objective and Background

In order to transmit a lot of information in efficiency at the information age which is quickly developed recently, the demand of a display medium is increasing rapidly. This micro display was mainly used from in the past by the display of 1 inch or less of diagonals by head mounted display (HMD) at the object for military affairs. Now it has continuously developed with the micro EGD that can put on and take off glasses. The composition element of EGD consists of the display or image source, the optics through which the display is viewed, and the means by which the display and optics are mounted on the glasses[1]. Image source used CRT element at past but it has been developed at present [2], such as liquid crystal display (LCD), field emission display (FED), liquid crystal on silicon (LCoS), organic light emitting device (OLED), etc.

Optic system carries out the most important duty among EGD that it can make it possible to see the image in microdisplay. This is magnified by virtual image, and the user can see it. The paper used one aspheric lens, in order to minimize optic system, and on the other hand, it constituted it from DOE in the field for the improvement in a performance.

2. Optical Design for EGD

We used reflective liquid crystal on silicon SVGA (800 x 600) 0.6 inch with microdisplay panel for optical design. Reflective LCoS has used HMD, Head-up-displays and Projection display because can reduce pitch of pixel, high aperture, the low cost and compact system size[3]. Fig. 1 shows scheme of basic EGD with reflective LCoS microdisplay.

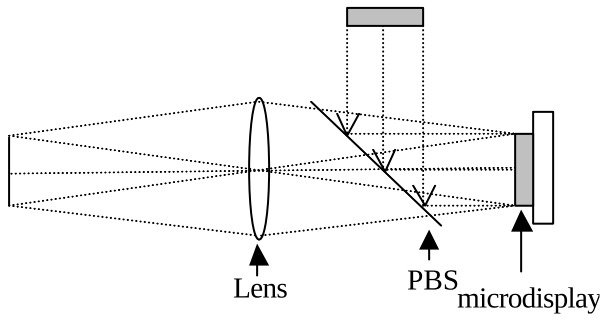

Fig.1 Scheme of basic EGD with reflective LCoS microdisplay. PBS : Polarization beam splitter

2.1 EGD Optical Characteristics

The parameters used to describe an EGD are field of view (FOV), eye relief, exit pupil diameter etc. Field of view is optical FOV and actual FOV. Optical FOV does not depend on diameter of simplicity magnifying glass lens, but actual FOV is depended on diameter of magnifying glass lens and pupil distance. From Fig.2 optical FOV can be calculated using Eg. 1[4].

$$FOV = 2\arctan\left(\frac{S}{2F}\right) \quad \text{[degrees]} \quad (1)$$

where FOV = field of view

S = size of display

F = focal length of lens

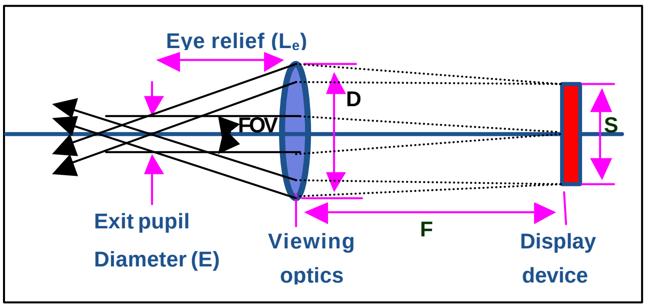

Fig. 2 Optics parameters of EGD optics

Actual FOV is given by

$$FOV = 2\arctan\left(\frac{D}{2L_e}\right) \quad \text{[degrees]} \qquad (2)$$

where FOV = field of view (actual)

D = diameter of magnifier lens

L_e = eye distance from lens

Note : this equation is valid only when $D<L_e(S/F)$.

As eye relief (L_e) sees in Fig. 2, it is distance from actual eye position to the nearest lens of the EGD optics. Therefore, if eye relief is long, it can use putting on glasses because position of eye can see away with EGD. However, it is suitable about 20 - 25 mm in actual EGD optic because exit pupil size(or eye motion box) is decreased if eye relief is so long. The following is equation that shows relation with eye relief and exit pupil size [4].

$$E = D - \frac{L_e S}{F} \qquad (3)$$

where E = exit pupil diameter (eye motion box size)

D = lens diameter

S = display size

F = lens focal length

L_e = optical eye relief distance

2.2 Design target and design result

To see the magnified virtual image of micro display, optical system is as following. 1. Pupil size is 6 mm, 2. Eye relief is 20 mm, 3. FOV is 35 degree. Optical system for EGD is most important above 3 to compose optic. Usually, effective focal length of EGD optic is suitable about 20 - 30 mm, and FOV is by 25° 35° (horizontal) x 20° 25° (vertical) degrees[5]. The specifications of the optic are listed in the second column of the table 1. We can see that most parameters attain the targets. But MTF at full field is some lacking in target number. This is very difficult to make using single lens. But this is thought there is no problem to apply to EGD.

Table 1. The specifications of the lens in comparison with proposed designing targets

	Target	Result
Field of view (°)	35	35.23
Focal Length (mm)	25	25.6
Image Size (mm)	16	16
Distortion	<3 %	<2 %
MTF (Full field)	30 %	20 %
Virtual Image Size	45"at 2m	50" at 2m
Eye Pupil Diameter	8	6
Eye Relief (mm)	20 30	20

2.3 Design of aspheric lens

The aspheric is usually represented as a tenth-order polynomial. Let z(r) be the surface sag, r the ray height, and c the curvature of the surface at the optical axis [5]. Then,

$$z(r) = \frac{cr^2}{1+\sqrt{1-(1+k)c^2r^2}} + Ar^4 + Br^6 + \cdots + Jr^{20} \qquad (4)$$

where $r^2 = x^2 + y^2$

k = conic constant

A, B,···, H, J = aspheric deformation coefficient

2.4 Design of Diffractive optical engine

Diffractive optical engine (DOE) is observed because it has small volume and improve optical property. Kinoform is DOE making the phase profile on thin material, mainly made approximation stair form [6].

If it make in saw tooth shape so that phase of wavelength may have phase structure of 2π, phase φ(r) is expressed with Eq.5.

$$f(r) = \frac{2p}{l_0} \sum C_n r^{2n} \qquad (5)$$

Where λ_0 is reference wavelength and C_n is second coefficient. If substrate with wavelength λ_0 has n_0 of refraction index, thickness of lens is expressed with Eq. 6.

$$d = \frac{l_0}{n_0 - 1} \qquad (6)$$

We designed side with panel by DOE using above way. Medium of optic lens can minimize weight using Zeon company's Zeonex E48R plastic material. Also, price is inexpensive because is easy to engrave aspheric and DOE's shape, and mass production is available. However, general plastic materials are shortcoming that refractive index is low and species are not various.

Table 2. Designed optic data for EGD

<table>
<tr><th>No</th><th>Radius (mm)</th><th>Thickness (mm)</th><th>Glass</th></tr>
<tr><td>object</td><td>Infinity</td><td>Infinity</td><td></td></tr>
<tr><td>stop</td><td>Infinity</td><td>20</td><td></td></tr>
<tr><td>2</td><td>27.4546</td><td>5.925</td><td>E48R</td></tr>
<tr><td colspan="4">ASP K -0.527078
A 0.29672E-4 B 0.270219E-6
C -0.465843E-8 D 0.499166E-10</td></tr>
<tr><td>3</td><td>-29.1488</td><td>24.0749</td><td></td></tr>
<tr><td colspan="4">ASP + DOE K -75.559857
A -0.219516E-3 B 0.466755E-5
C -0.464610E-7 D 0.220437E-9
C1 -1.5497-3 C2 1.6031E-5
C3 -3.0946E-7 C4 2.6191E-9
C5 -8.2223E-12</td></tr>
<tr><td>image</td><td>Infinity</td><td></td><td></td></tr>
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Next, it is a picture showing the result of having carried out the simulation of an optical system. Fig. 3 shows optics ray tracing that it is designed optical system by image surface to micro display panel. Stop aperture is situated actual eye. We did ray tracing with 5 fields to center on optical axis and optical axis through stop. The field curvature/distortion of the proposed aspheric singlet EGD is shown in Fig. 4. From Fig. 4 we can see that the maximum field curvature is 0.6 mm for the tangential and sagittal orientation. And we can see that the maximum distortion is less than 0.2 %, which can be described as the sum of perspective distortion. The curves of MTF are shown in fig. 5. We can see that MTF in tangential of full field come out by more than 20 %. Finally, figure 6 is that displays distortion result by forward direction image.

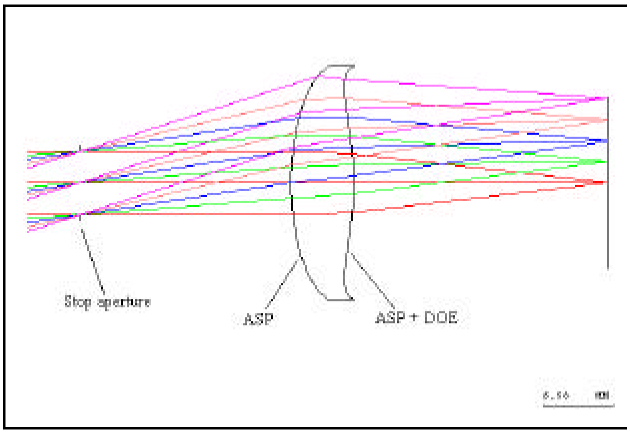

Fig. 3 Optics ray tracing

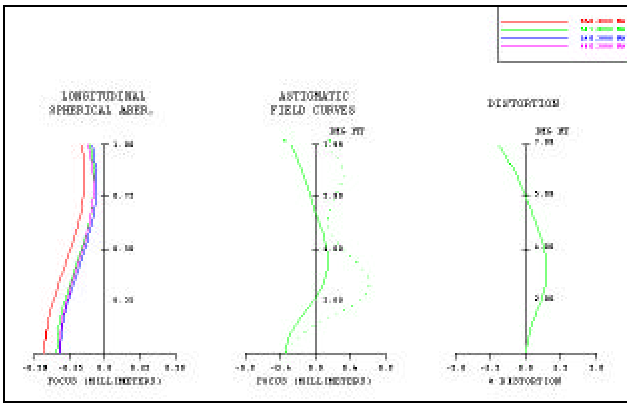

Fig. 4 Astigmatism, Spherical aberration, Distortion

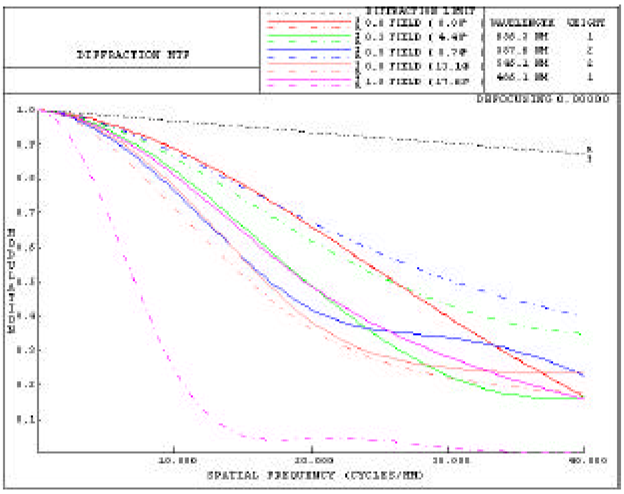

Fig. 5 The modulation transfer function (MTF) of the optical system

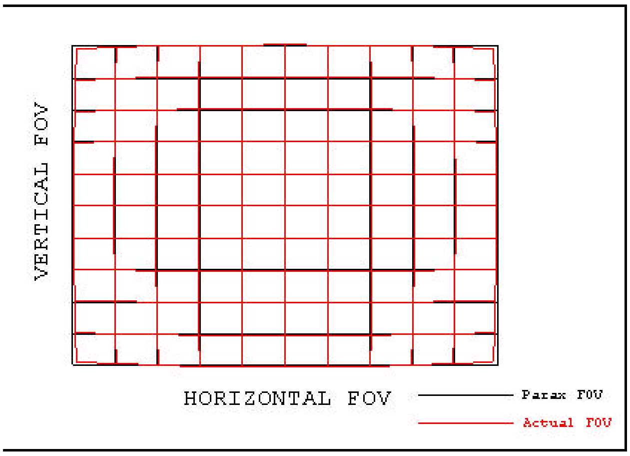

Fig. 6 Result of distortion

3. Result

In this research, we reduced distortion of less than ±2% using an aspheric lens to microdisplay of LCoS 0.6" panel, and virtual image showed more than 50" at 2m. One aspheric lens is used and it is designed being most suitable about the optimal optical system. The advantageous of the optical design provide lighter weight and lower complexity for EGD.

4. Acknowledgements

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5. References

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