Development of 40 inch hybrid hologram screen for auto stereoscopic video display

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ABSTRACT

Usually in auto stereoscopic display, there are two problems. The first problem is that large image display is difficult, and the second problem is that the view zone (which means the zone in which both eyes are put for stereoscopic or 3-D image observation) is very narrow. We have been developing an auto stereoscopic large video display system (over 100 inches diagonal) which a few people can view simultaneously[1),2)]. Usually in displays that are over 100 inches diagonal, an optical video projection system is used. As one of auto stereoscopic display systems the hologram screen has been proposed[3),4),5),6)]. However, if the hologram screen becomes too large, the view zone (corresponding to the reconstructed diffused object) causes color dispersion and color aberration[7)].

We also proposed the additional Fresnel lens attached to the hologram screen. We call the screen a “hybrid hologram screen”, (HHS in short). We made the HHS 866mm(H)×433mm(V) (about 40 inch diagonal)[8),9),10),11)]. By using the lens in the reconstruction step, the angle between object light and reference light can be small, compared to without the lens. So, the spread of the view zone by the color dispersion and color aberration becomes small. And also, the virtual image which is reconstructed from the hologram screen can be transformed to a real image (view zone). So, it is not necessary to use a large lens or concave mirror while making a large hologram screen.

Keywords: auto stereoscopic, two view, hybrid hologram screen, color distribution, color aberration

1. Introduction

Auto stereoscopic display means to see a 3-D image without wearing special glasses. As for 3-D image display system that can make this auto stereoscopic display, convex lens type, lenticular lens sheet type, and hologram screen type have been developed. But this auto stereoscopic display type usually has a narrow view zone. As the display screen enlarges we can observe a more realistic 3-D image, but it is difficult to make a large screen. As such, it is required to

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have a wide view zone and large screen.

This study developed the diagonal 40 inch hybrid hologram screen which uses two view types to make the 3-D image display system, utilizing holography technology. The following will introduce the principle of the 3-D image display using the hybrid hologram screen, how HHS was made, and the performance of the view zone.

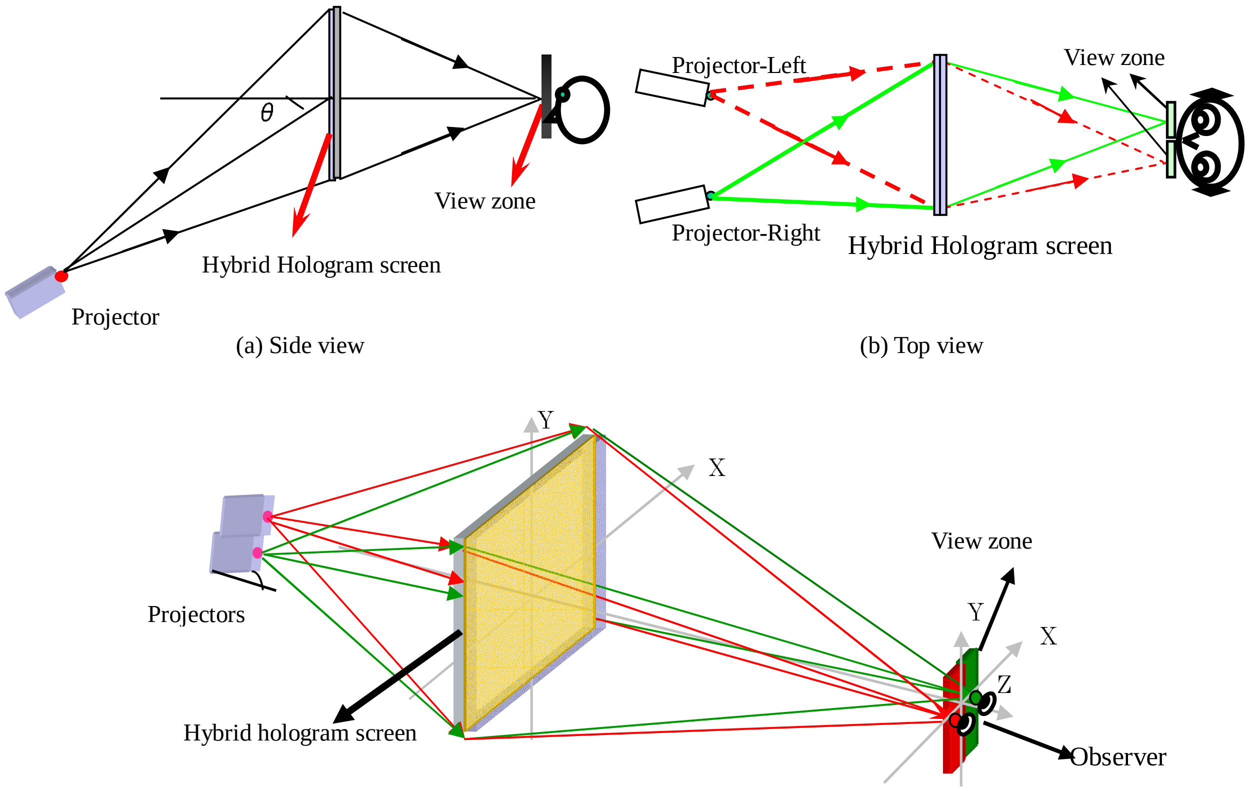
2. Principle of seeing the 3-D image for auto stereoscopic using the hybrid hologram screen

The hybrid hologram screen is a combination of the Fresnel lens and hologram screen. In figure 1 we can see the principle of the auto stereoscopic 3-D image display system using the hybrid hologram screen. We can naturally observe the auto stereoscopic without wearing special glasses. With regard to the principle of auto stereoscopic display using the hybrid hologram screen: project 2-D images to the whole area of the hybrid hologram screen from the two projectors that the left and right eyes will observe separately. At this time, view zone is the position in which the observer puts their left and right eyes to see the 3-D images. The 2-D images are illuminated to the hybrid hologram screen from the projectors simultaneously. The hologram screen reconstructs the virtual image of the ground glass which was the object light at the time of recording. The Fresnel lens converts the virtual image to the real image.

At this time, color dispersion and color aberration occurs on the hologram screen. This problem occurs because the light used for recording and for illumination are not the same. If the effects of color dispersion and color aberration are too big in the view zone, the observer cannot see natural color 3-D image.

It is possible to decrease the effects of color dispersion and color aberration. To do so, it is necessary to the incidence angle of reference light low. In this way, it may decrease effects of color dispersion and color aberration. However, when the incidence angle of reference light is small the 0 order light directly transmits into the vision of the observer, and it interrupts the observation of the 3-D image. To solve the problem of 0 order light in the hybrid hologram screen, the Fresnel lens makes the imagery of 0 order light at another location, separate from that of the view zone.

The hybrid hologram screen can adjust the view zone at the time of reconstruction by changing the conditions of the ground glass at the time of recording. In addition, it is possible to decrease the effects of color dispersion and color aberration at the view zone by making the size of the hologram screen larger.



(a) Side view

(b) Top view

(c) The sketch of the reconstruction using hybrid hologram screen

Fig1. Principle of observe the 3-D image for two view types an auto stereoscopic using the hybrid hologram screen

3. Calculation of color distribution and color aberration

Usually as the size of the hologram screen gets larger, color dispersion and color aberration are expected to increase. Therefore, it is very important to decrease the effects of color dispersion and color aberration at the time of recording the hologram screen. To examine the color dispersion and color aberration generated due to the change of light wavelength, numerical value was calculated using the hologram imagery formula shown in (1), (2), (3). The object light is the light of diffusion using the ground glass when making the hologram screen. The ground glass is the view zone at the time of reconstruction.

As for the detailed setting conditions for calculating the color dispersion and color aberration, the size of the hologram screen was set at 433mm(V)×866mm(H). The focal length of the Fresnel lens at the time of reconstruction was set at 1200mm. The size of the Fresnel lens is 433mm(V)×866mm(H). As for the size of the ground glass, the horizontal length was set at 40mm, and vertical length was set at 200mm in consideration of the imagery magnification of the Fresnel lens. The vertical length was set to 200mm so that the overlapping length at the observation position will be over 100mm when the light of three wavelengths of 488nm, 532nm, 633nm are illuminated. The incidence angles of reference light and illumination angles were set to 15 degrees. The wavelength of illumination light was calculated by determining the three wavelengths of 488nm, 532nm and 633nm.

Figure 2 shows this detailed calculation. In making the hologram screen, it is assumed the wavelength of the recording laser and incidence angle of reference light. After that, the position of point A on the ground glass is assumed. Next the position of point B on the hybrid hologram screen is assumed. Then the direction and angle of the diffracted light (C in Figure 2) from the hybrid hologram screen is obtained after it passes through the Fresnel lens and hits the view zone. At this time, it is assumed that the Fresnel lens has no aberration.

Figure 3 is the calculation result of color dispersion and color aberration on the view zone after the image is illuminated by the horizontally aligned two projectors.

$$\frac{1}{\lambda_c}\left(\frac{1}{Ri}-\frac{1}{Rc}\right)=\frac{1}{\lambda_R}\left(\frac{1}{R_o}-\frac{1}{R_r}\right) \quad (1)$$

$$\frac{1}{\lambda_c}\left(\frac{X_i}{R_i}-\frac{X_c}{R_c}\right)=\frac{1}{\lambda_R}\left(\frac{X_o}{R_o}-\frac{X_r}{R_r}\right) \quad (2)$$

$$\frac{1}{\lambda_c}\left(\frac{Y_i}{R_i}-\frac{Yc}{R_c}\right)=\frac{1}{\lambda_R}\left(\frac{Y_o}{R_o}-\frac{Y_r}{R_r}\right) \quad (3)$$

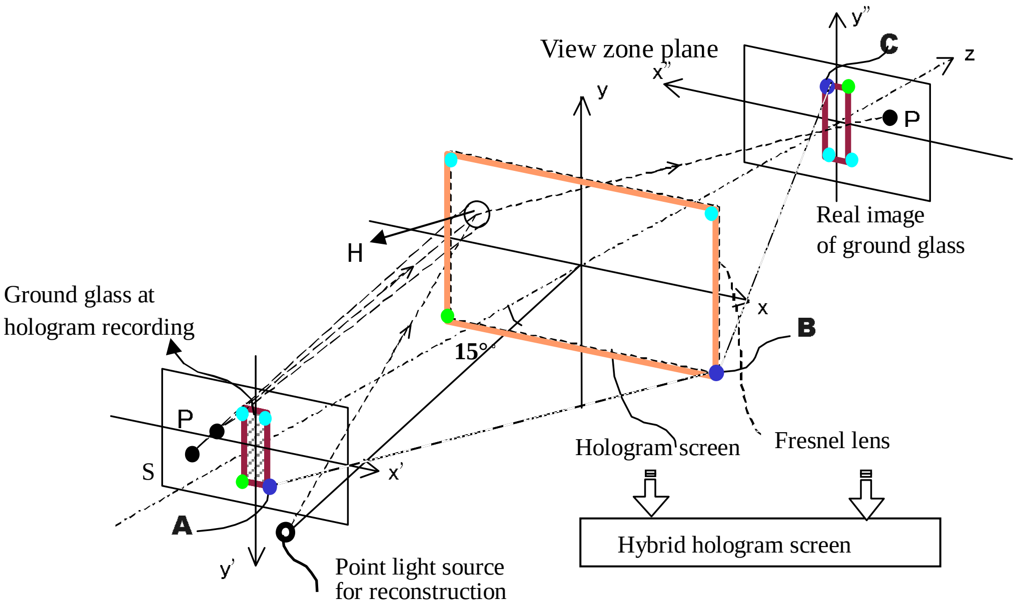


Fig2. Calculation of color distribution and color aberration on the hybrid hologram screen

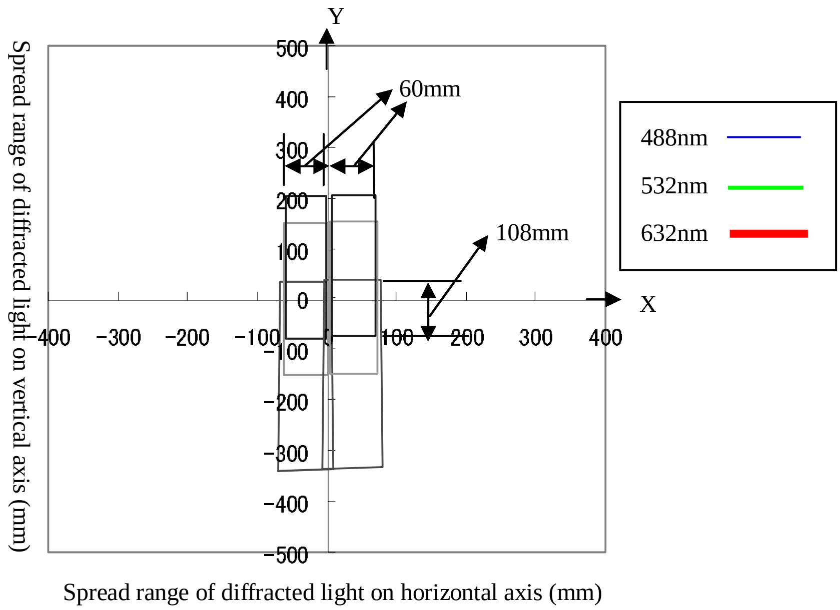


Fig3. Result of calculation color dispersion and color aberration about the two view zones on the observation position

4. Making of the 40 inch diagonal hybrid hologram screen

Figure 4 shows the optical set up to make the hybrid hologram screen 40 inches in diagonal. As shown in Figure4, reference light is spherical light that diverges from the point. Because of this, we can make the large hologram screen without using special optic devices such as large concave mirrors. In the mean time, object light is diffused light from the ground glass. The size of the width and length of the ground glass was determined as 200mm(V)×40mm(H). That is, the shape of the ground glass was a rectangle with a long vertical length. The ground glass and hologram screen were set parallel to each other at the time of recording. The incidence angle of reference light was set to 15 degrees at the center of the hologram screen. An SHG laser with a wavelength of 532nm was used for recording. The recording material is a silver halide plate from Konica. The size of one side of the plate is 433mm squares, so connecting two plates together at the time of making the hologram screen gives a 40 inch diagonal. For development and bleaching the MA and EDTA process is used. After that it is dried naturally.

5. Measurement of performance at the view zone

Whole area of the screen is illuminated by three wavelengths of 488nm, 532nm, 633nm lasers and white light (slide projector) from the reference point. The incidence angle of illumination light was set at 15 degrees at the center of the hybrid hologram screen. And the Fresnel lens is attached to the hologram screen. Figure 5 (a), (b), (c), (d) is a picture of the results of the shape of the view zone that was projected on white paper at the observation position. At that time, we measured the view zone that was reconstructed at the observation position 3000mm away from the hybrid hologram screen. We examined the distribution of light intensity in the vertical and horizontal directions. The first thing we determined was the vertical location that has the maximum distribution of light intensity in the view zone.

After that, we measured the intensity of the light in 10mm intervals in the horizontal direction. The results are shown in Figure 6(a), (b). Figure 6(b) shows the HW(50mm) corresponding exactly to the observed 3-D full color image at the time of illumination to the whole area of the hybrid hologram screen.

In addition, we illuminated 2-D images on the whole area of the hybrid hologram screen using four slide projectors. Four horizontal view zones were reconstructed at the observation position. We measured the distributions of light intensity in the four view zones. The method of measurement is the same as the above-mentioned method.

Figure 7(a) shows the photography pattern of light intensity at four view zones. Four view zones are reconstructed in the observation position by illuminating the whole area of the hybrid hologram screen using the four slide projectors. Figure 7(b) shows the measured result of the distributions of light intensity in the four view zones. Result of the measured the distributions of light intensity in the two or four view zones shows that 3-D full color image at the horizontal width of 50mm(H1 in figure 5(a)) on the observation position. The distribution of light intensity was known to not be uniform as compared to the shape of the ground glass at the time of recording. The reason is that the diffused light from the ground glass was uneven.

As for the vertical length of view zone in which natural color image can be observed was designed about 100mm. But the made HHS has only 20mm (V1 in figure 5(a)). The reason of the shortening is considered to the change at the view zone by the same causes mentioned above, that is, the intensity change exists to vertical direction..

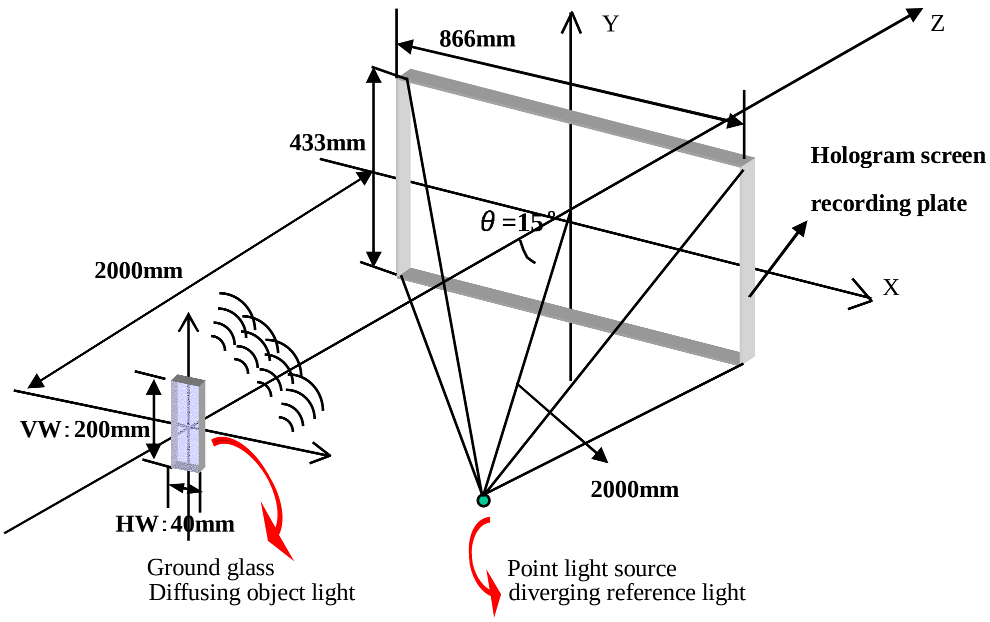
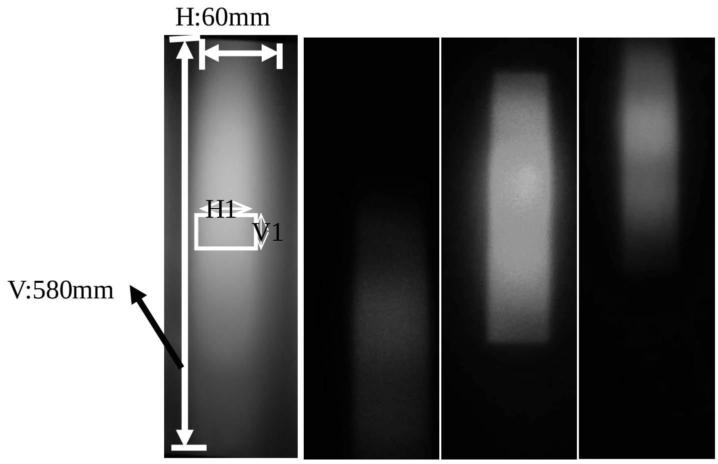
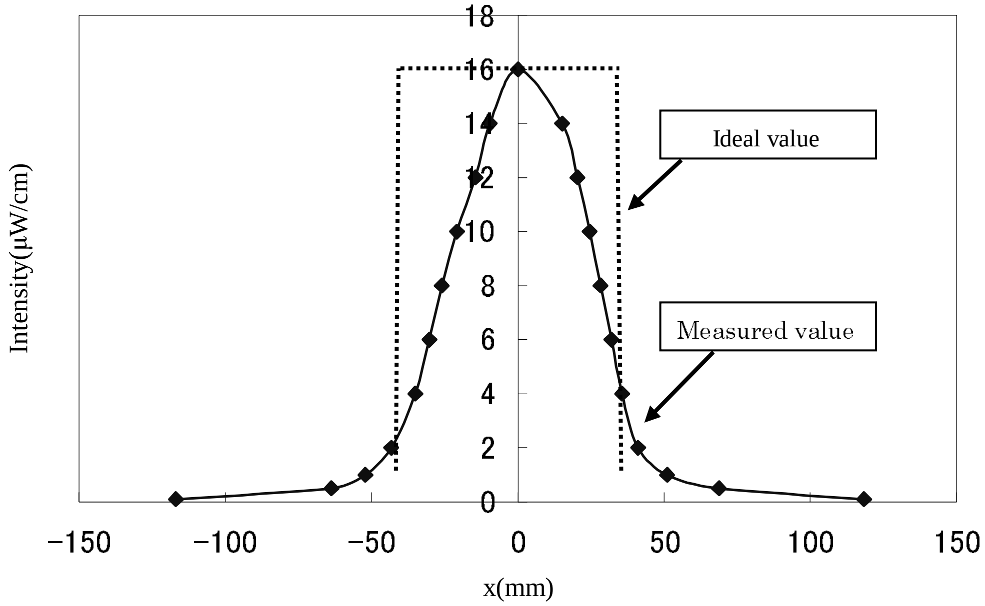


Fig4. Optical set up make for the 40inch diagonal hologram screen

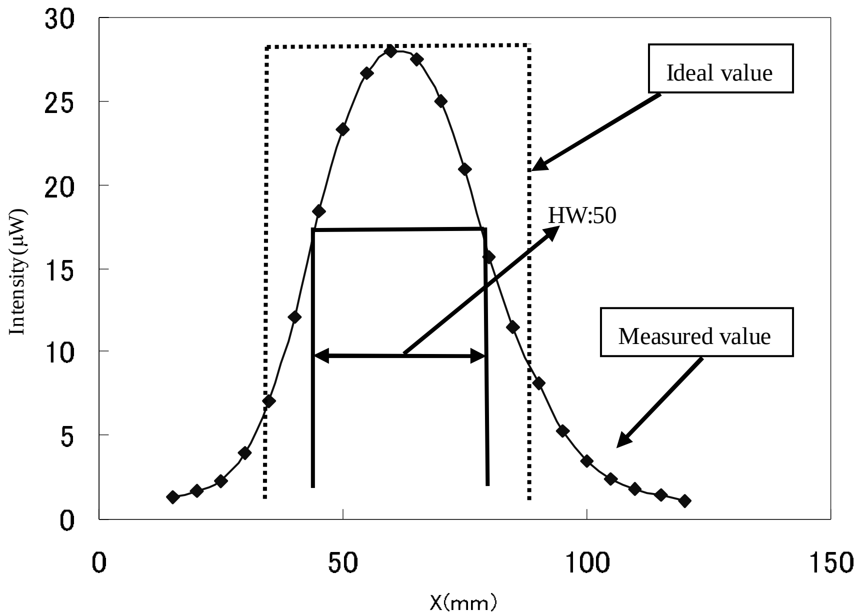


(a) White light (b) 633nm (c) 532nm (d) 488nm

Fig5. Photo of intensity pattern on view zone when illuminating white light and 633nm(Red), 532nm(Green), 488nm(Blue) lasers to the hybrid hologram screen. In the V1(20mm) ×H1(50mm) position is that we can see the full color 3-D image observation position in (a).



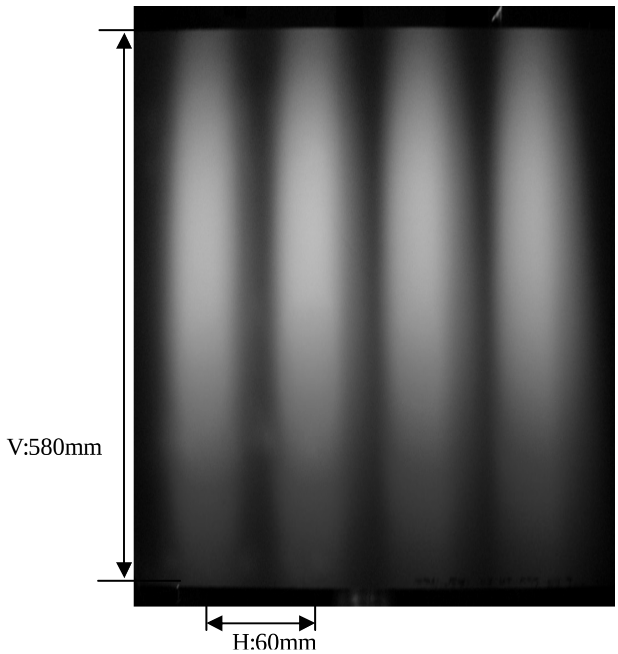
(a) Result of measured intensity of horizontal view zone when illuminating 532nm laser to whole area the hybrid hologram screen



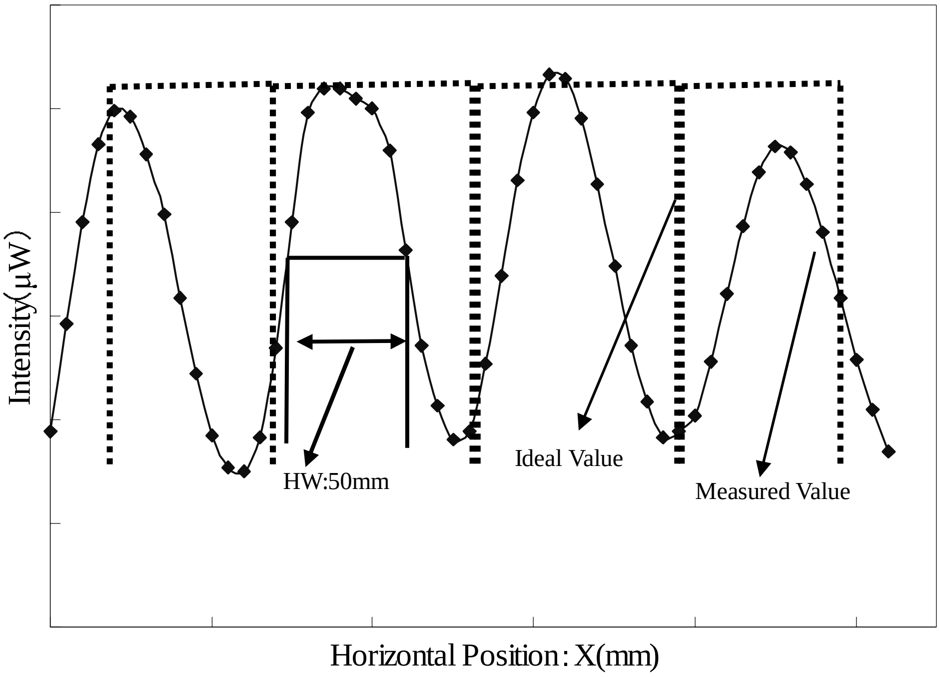
(b) Result of measured intensity of horizontal view zone when illuminating slide projector to whole area the hybrid hologram screen

Fig6. Result of measured intensity of horizontal direction at view zone of the hybrid hologram screen

(Dashed line is ideal value data on graph)



(a) Photo of intensity of four view zones while illuminating four slide projectors to the hybrid hologram screen



(b) Result of measured intensity of horizontal four view zones when illuminating four slide projectors to the whole area the hybrid hologram screen

Fig7. Photo of intensity pattern and measured intensity to horizontal direction when illuminating four slide projectors to whole area the hybrid hologram screen

6. Conclusion

We developed the 40 inch diagonal hybrid hologram screen which can be used to an auto-stereoscopic display system. We can make the 40 inch hybrid hologram screen using the reference light diverged from the point source light. So it is not necessary to use a large lens or concave mirror to make the size of the hologram screen larger. The Fresnel lens converts the virtual image to the real image which is view zone of each eye. Also, it is accepted that the angle of reference light can be small. So, the spread of the color dispersion and color aberration in the view zone becomes small. We were able to see the larger color 3-D image in the 40 inch screen, but the narrow view zone was a problem. There are plans to make large hybrid hologram screens that allow a few observers to see the 3-D color image at the same time as well as making wider view zones.

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