Handmade Glasses-free 3D Viewer Using Commercial DIY Goods

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***Abstract*— We developed a glasses-free 3D stereoscopic display using an LCD display panel and a special grating film for stereoscopic viewing. The display screen is divided in half in order that left and right regions provide the stereoscopic images for left and right eyes. Because both stereoscopic images are not in the same position, it is difficult for the observer to view the 3D image by the stereoviewing. The grating film can solve this problem because it shifts both left and right images to the same position. Moreover this grating film can give us glasses-free 3D viewing because of its view control effect. As the result, the observer can watch overlapped stereoscopic images for left and right eyes without special glasses such as polarized glasses.**

***Index Terms*—3D imaging, stereoscope, optical grating film, overlapping stereoscopic images, viewing angle control film**

I. INTRODUCTION

Conventional 3D movie systems with the special glasses such as polarized glasses provide us touchable spatial images. However, these 3D imaging systems are very expensive and large scale equipment. Our research group would like to realize the simple 3D imaging system to construct an interactive spatial imaging environment. The authors have researched the 3D displays and applications. We have ever proposed 3D displays using the slit as a parallax barrier, the lenticular screen and the holographic optical elements(HOEs) for displaying active image[1][2][3]. In this paper, we describe the 3D adapter using an optical grating film, which is sold at stores, for easy 3D image viewing.

A liquid crystal display (LCD) recently comes into common use. When the screen is divided in half, it can display two stereoscopic images in the same size. The left and right regions provide the stereoscopic images for left and right eyes. An LCD screen has the characteristic of polarization. For example, when a 1/2 wave plate is attached to the right region, the observer, who wears the polarized glasses, can view the separated left and right stereoscopic images. However, both stereoscopic images are not in the same position because both centers of left and right regions have an interval, then it is difficult for the observer to view the 3D image by the stereoviewing.

One of the solutions to this problem is to use the 4-mirror stereoscope. This 4-mirror stereoscope is an easiest way to see stereoscopic images. But this paper describes another solution.

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Fig. 1 3D TV broadcast

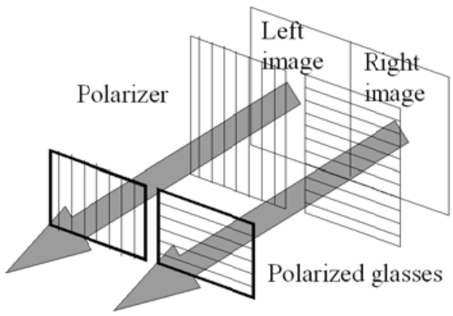

Fig. 2 Stereoscope using polarized glasses (parallel viewing)

II. MOTIVATIONS

Nippon BS Broadcasting Corporation (BS11 digital) started the BS11 3D television programming in 2007. To watch this program, we need a special TV display which can decode the BS11 3D broadcast signal format. In case of a conventional TV monitor, we observe a side-by-side stereoscopic image as shown in Fig. 1. If the screen is divided in half, it enables us to display left and right stereoscopic images in the same size. A LCD or a plasma display recently comes into common use. An LCD screen has the characteristic of polarization. As shown in Fig. 2, the left and right regions provide the stereoscopic images for left and right eyes. For example, when the 1/2 wave plate is attached to the right region, the observer, who wears the polarized glasses, can view the separated left and right stereoscopic images. However both stereoscopic images are not in the same position because the center of left and right regions has an interval, then it is difficult for the observer to view the 3D image by the stereoviewing. If the display unit

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emits orthogonal polarized rays, *e.g.*, vertical polarized left and horizontal right images, and overcomes the image position problem, we can enjoy 3D TV programs using any monitor.

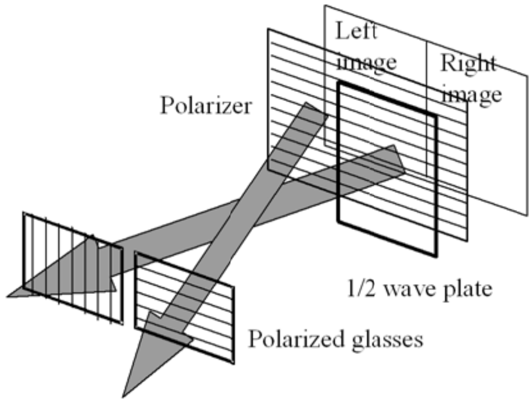

Fig. 3 Stereoscope using polarized glasses (cross-eyed viewing)

III. Glasses 3D Vision Using Side-by-side Images

A liquid crystal display recently comes into common use. When the screen is divided in half, it can display two stereoscopic images in the same size. As shown in Fig. 2, the left and right regions provide the stereoscopic images for left and right eyes. An LCD screen has the characteristic of polarization. For example, when the 1/2 wave plate is attached to the right region, the observer, who wears the polarized glasses, can view the separated left and right stereoscopic images.

An ordinary cellophane wrap can be used to turn a laptop computer screen into a 3D display[4]. The cellophane wrap can rotate the polarization of light such as the 1/2 wave plate. Half the screen is covered with the cellophane to change its polarization. Thus the screen of an LCD is divided in half, with each side portraying slightly different images. When an observer uses a pair of glasses that are differently polarized, the right eye can see light coming from the left half of the screen only, and the left eye can see light from the right half of the screen only as shown in Fig. 3.

In these methods, both stereoscopic images are not in the same position because both centers of left and right regions have an interval. The observers are required to force their eyes either to cross, or to diverge, to perceive a 3D image and thus it is difficult for the observer to view the 3D image by the stereoviewing.

To solve this unnatural 3D viewing problem, we developed the 3D adapter using an optical grating film for stereoscopic viewing. The principle is very simple. The optical grating film shifts both left and right images to the same position. The observer watches overlapped stereoscopic images for left and right eyes. But it is possible to separate left and right images when the observer wears polarizer glasses. This optical grating film is thin and works as a prism. The optical film appropriately locates apart from the display panel so that stereoscopic left and right images are overlapped.

The prototype stereoscopic display consists of a commercial 7 inch LCD panel. The screen size of an observed image is 55x70 mm because of dividing a screen in half. We attached a quasi 1/2 wave plate to the half region on the screen. Hence the left image has vertical polarization and the right image has horizontal polarization, for example, because the LCD panel has unidirectional polarization. When the observer wears the polarized glasses, left and right images are separated and stereoscopic 3D images can be observed.

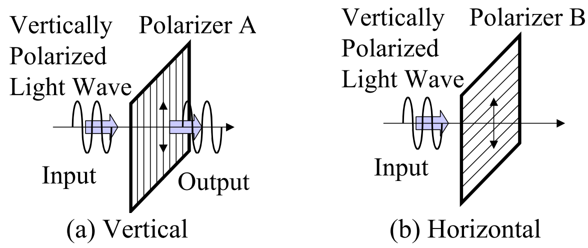

Fig. 4 Polarizer

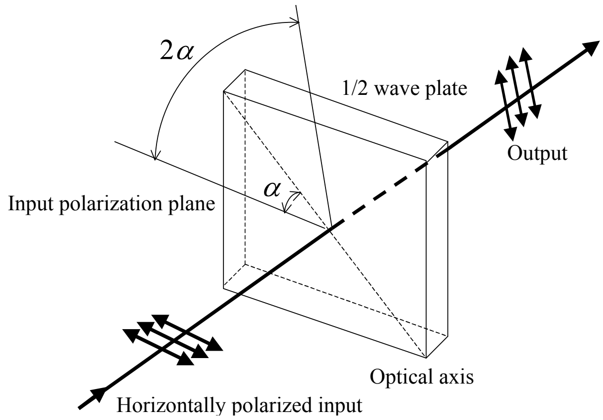

Fig. 5 1/2 wave plate

IV. Polarization Control Technique

A. Polarizer

There are two types of polarizing filters, polarizers for short: linear and circular. Fig. 4 shows the basic concept of polarization using the linear polarizer. In this example, the linearly polarized incident light is vibrating vertically before encountering the polarizer, a filter containing long-chain polymer molecules that are oriented in a single direction. Only the incident light that is vibrating parallel to the polarization direction is allowed to pass. Therefore, since polarizer A is oriented vertically, it only permits the vertical waves in the incident beam to pass. However, the vertically polarized waves are subsequently blocked by polarizer B because it is oriented horizontally and absorbs all of the waves that reach it due to their vertical orientation.

B. 1/2 Wave Plate

The 1/2(half) wave plate can be used to rotate the polarization state of a plane polarized light as shown in Fig. 5. Suppose a plane-polarized wave is normally incident on a wave plate, and the plane of polarization is at an angle α with respect to the fast axis, as shown. After passing through the plate, the original plane wave has been rotated through an angle 2α. Therefore, the incident light is horizontally polarized wave at

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45 degrees with respect to the axis, the output wave is vibrating vertically.

Fig. 6 Quasi-1/2 wave plate (acrylic resin plate)

Fig. 7 Quasi-1/2 wave plate (card case)

Fig. 8 Doubling phenomenon

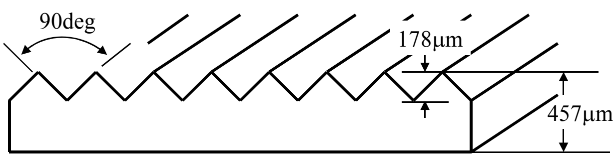
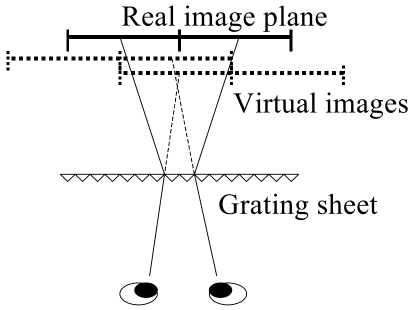


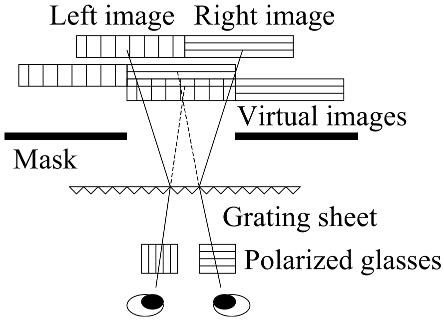
Fig 9 Structure of optical grating sheet

C. Quasi 1/2 Wave Plate

The surface of an LCD panel emits unidirectional polarized lights. To generate orthogonal polarized left and right images, the half of a panel must be covered with a wave plate. However, a commercial wave plate is small and very expensive. Being at a loss, the authors found some plastics work as the 1/2 wave plate. These materials are an acrylic resin plate and a plastic card case sold in Daiso. The Daiso is the largest franchise of 100-yen shops in Japan. Fig. 6 shows an acrylic resin plate which is sandwiched by two polarizers. As the plate rotates the direction of polarization, a part of the sandwiched plate passes the light on condition both polarizers are orthogonal and blocks the ray in case of the same direction of polarizers. Meanwhile piled two card cases, as double layer is just good, also function as the 1/2 wave plate as shown in Fig. 7. Thus it turned out that some Daiso's plastic materials work as the 1/2 wave plate.



(a) Superimpose images



(b) Stereo viewing

Fig. 10 Overlapping left and right images

V. PROTOTYPE GLASSES-TYPE 3D ADAPTER

A. Motivations

The authors found an interesting material at Tokyu Hands in Shinjuku, Tokyo, Japan. Tokyu Hands is one of the more interesting Do-It-Yourself type stores in Japan. There are many interesting gadgets, gifts, hobby or craft items you might want. The item, which we found, is the optical film and it is named "SOLF". The SOLF optical sheet is a flexible film with prisms designed to transport and diffuse the light. This sheet has interesting characteristics as follows; the prismatic phenomenon is observed and the doubling can be visible through the sheet like the Calcite. This doubling phenomenon occurs because the prism sheet diffracts two beams. These beams are called as the first order diffracted beam and the second order diffracted beam. Fig. 8 shows the doubling phenomenon. This interesting phenomenon reminds us of method to superimpose left and right stereoscopic images.

B. Superimpose stereoscopic images

Fig. 9 shows the structure of the optical grating sheet. A grating diffracts or scatters a light beam with a designed angle. This sheet provides us with a doubling image as shown in Fig. 8. Using this characteristic, the authors shift the images for superimposing stereoscopic images by adjusting the interval between an optical sheet and image plane as shown in Fig. 10(a). We developed the 3D adapter using this optical grating film for stereoscopic viewing. The optical grating film shifts both left and right images to the same position. The observer watches overlapped

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stereoscopic images for left and right eyes. But it is possible to separate left and right images when the observer wears polarized glasses. This optical grating film is thin and works as a prism. The optical film appropriately locates apart from the display panel so that stereoscopic left and right images are overlapped. As shown in Fig 10(b), the vertically oriented polarizer is attached on the left half of an image plane. Then an image for the left eye has vertically oriented polarization. Meanwhile, a right eye image has horizontally polarization because the right side of an image plane is covered with a horizontally oriented polarizer. The orthogonal polarized stereoscopic images are overlapped on the same plane. If the observer wears the polarized glasses, he can perceive the left image only by a left eye and the right image by a right eye. Therefore, the observers, who wear the glasses, can view the 3D images by the binocular stereo viewing.

(a) desktop screen

(b) overlapped image through grating film

Fig. 11 Desktop screen of laptop computer

C. *Experiments*

Fig. 11 shows the prototype display using a commercial laptop computer. The size of an LCD display is 12.1 inch. This LCD screen is divided in half to display a left image for the left eye and a right image for the right eye as shown in Fig. 11(a). Though the LCD panel is utilized as the displaying plane of side-by-side stereoscopic images, stereoscopic left and right images are overlapped by a grating film. This grating film plate is positioned 70mm apart from the display panel. The observer perceives an overlapped image through the grating film as shown in Fig. 11(b). If the observers wear the polarized glasses, they can view the 3D images by the binocular stereo viewing

D. *Current Working Model*

We have developed the prototype display using a commercial portable DVD player. This player has a 7inch LCD panel which is utilized as the displaying plane of side-by-side stereoscopic images. The screen of an LCD is divided in half to display a left image for the left eye and a right image for the right eye. The LCD screens, which emit polarized light, light oscillating in a fixed direction. As quasi-wave plate is attached, the polarization direction of a right half screen is rotated in 90-degree angles so as to emit polarized light with orthogonal oriented polarizations. The grating film plate is positioned 50mm apart from the display panel so that stereoscopic left and right images are overlapped. The observer perceives an overlapped image through the grating film as shown in Fig. 12. As the observers wear the polarized glasses, they can view the 3D images by the binocular stereo viewing.

Fig. 12 Viewing screen of 3D display

Fig. 13 Appearance of 3D display (KNA-20X)

VI. IMPROVEMENT FOR GLASSES-LESS 3D VIEWING

Fig. 13 shows newly developed 3D display system. To deliver left and right images into appropriate eyes, we use a view control film “LUMISTY^{TM}”. The LUMISTY film is produced by Sumitomo Chemical Co., Ltd. Using this film, you can see through the film from the left, but not from the right as shown in Fig. 14. One of the miraculous features of LUMISTY is that it can be either transparent or opaque, so that it looks either like transparent or frosted glass, depending on the angle of sight. It is an adhesive-type transparent plastic film which can be used simply by sticking onto a windowpane, and it does not cut out any of the light coming through the window.

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(a) viewing at front

(b) viewing from side

Fig. 14 Effect of view control film

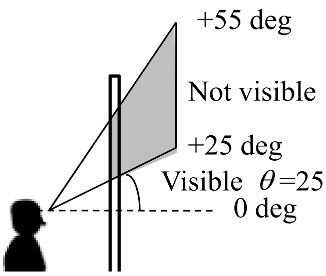

Fig. 15 View control

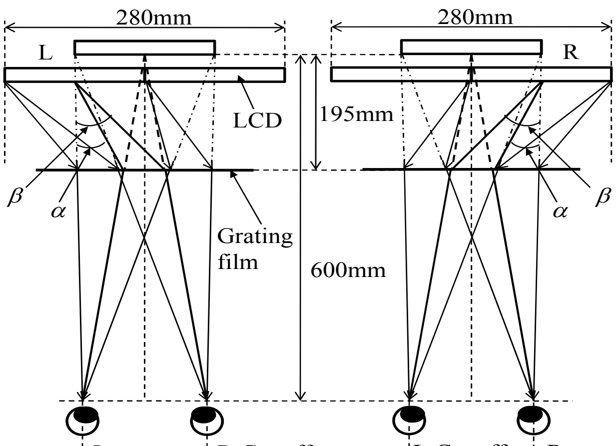

Fig. 16 Optical design of 3D adapter using view control

It is useful characteristics for 3D viewing that you can control what can and what cannot be seen depending on which side the viewer is on, or what angle the viewer is looking from. Using the miracle of this LUMISTY visibility control as shown in Fig. 15, it enables us to perceive left images by the only left eye and right images by the only right eye. As shown in Fig. 15, the view control film passes the light within an angle of θ. Let's design the optical layout assuming that 15-inch display panel is used. The width of the 15-inch panel is approximately 280mm. As shown in the Fig. 16, the ray of a left image is emitted with an angle α to vertical and it reaches into the left eye after the ray is diffracted by an optical grating film. Meanwhile the ray with an angle β passes into the right eye through the grating film. If the view control angle θ is α to β ($\alpha < \theta < \beta$), the left image is observed by the only left eye because the ray with an angle β to vertical is blocked by the optical film. The rays of a right image are the same as the left image. In case of the 15-inch panel, the angle α is 13.37 deg and the angle β is 25.64 deg. The LUMISTY film has many kinds of characteristics; *e.g.*, opaque from front side, one direction, two directions and so on. The grade MFY-2555 is opaque from one direction when the ray is encountering the film with the angle more than 25 deg. Using this MFY-2555 (θ=+25 deg), the observer can perceive the left image only by a left eye and the right image by a right eye with no glasses because the view control film restricts the direction of scattering light after the grating film overlays left and right images at the same position. Therefore, the observers, who wear no glasses, can view the 3D images by the binocular stereo viewing. We have developed the prototype glasses-free stereoscopic 3D display using two commercial LCD panels for playing 3D contents by portable DVD players as shown in Fig. 13. In this display, observers can view the 3D images by the binocular stereo viewing without special glasses.

VII. Newly Developed Glasses-less Viewing System

A. *View Control Effect of Grating Film*

The authors used the "SOLF™" optical film for overlapping left and right image as shown in Fig. 11. But you need to wear polarized glasses for separating stereo image. To deliver left and right images into appropriate eyes though you wear no glasses, we use a new grating film with view control effect. The author unexpectedly found this sheet in D.I.Y. materials floor at Sannomiya Store of Tokyu Hands. This product name is unknown. We regard this sheet as a cheaper copy product of the SOLF sheet. However this sheet has a useful characteristic. Using this film, you can see through the film from the left, but not from the right as shown in Fig 17. One of the miraculous features is that it can be either transparent or grating sheet, so that it looks either like transparent glass or prism, depending on the angle of sight.

It is useful characteristics for 3D viewing that you can control what can and what cannot be seen depending on which side the viewer is on, or what angle the viewer is looking from. Using the miracle of this visibility control as shown in Fig 17, it enables us to perceive left images by the only left eye and right images by the only right eye. As shown in Fig 18, the view control film passes the light within a designed angle. Let's design the optical layout assuming that 9-inch display panel is used. The width of the 9-inch panel is approximately 200mm. As shown in the Fig. 18, the ray of a left image is emitted with an angle α to vertical and it reaches into the left eye after the ray is diffracted by an optical grating film. Meanwhile the grating film doesn't diffract the ray with an angle β, which passes into the right eye. Therefore the left image is observed by the only left eye

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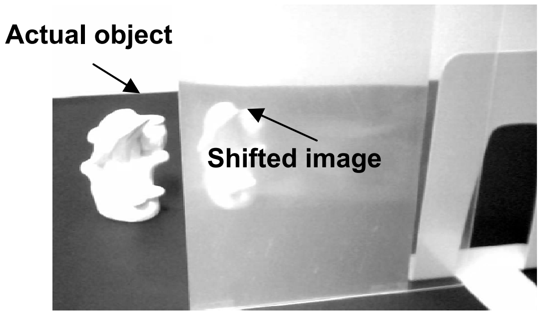
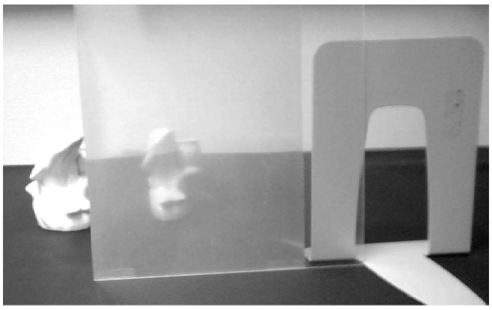
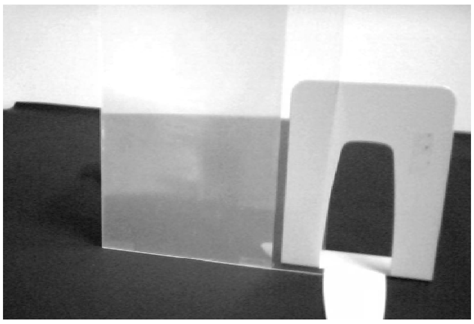
because the ray with an angle β to vertical is blocked by the optical film. The rays of a right image are the same as the left image. Using this grating film, the observer can perceive the left image only by a left eye and the right image by a right eye with no glasses because the film with view control effect restricts the direction of scattering light after the grating film overlays left and right images at the same position. Therefore, the observers, who wear no glasses, can view the 3D images by the binocular viewing.



(a) optical layout of experiment for left viewing



(b) viewing from left



(c) viewing from right

Fig. 17 View control effect of grating film

B. Current Working Model

We have developed the prototype glasses-free stereoscopic 3D display using two commercial LCD panels for playing 3D contents by portable DVD players. The size of panels is 7.24-inch and its width of viewscreen is 103mm. Assuming the 9-inch panel, the interval between the center of viewscreen is 200mm. Both panels are side-by-side and each LCD displays a left image for the left eye and a right image for the right eye. The grating film plate is positioned 92mm apart from the display panels so that stereoscopic left and right images are overlapped. The observer perceives an overlapped image through the grating film as shown in Fig. 19. In trial display, the observation distance is 400 mm. Because of overlapping images by optical film, the observer can see the 3D image at approximately 300 mm apart from a viewing window of a display box. Since viewing positions of left and right images are restricted, the observers can view the 3D images by the binocular stereo viewing without special glasses.

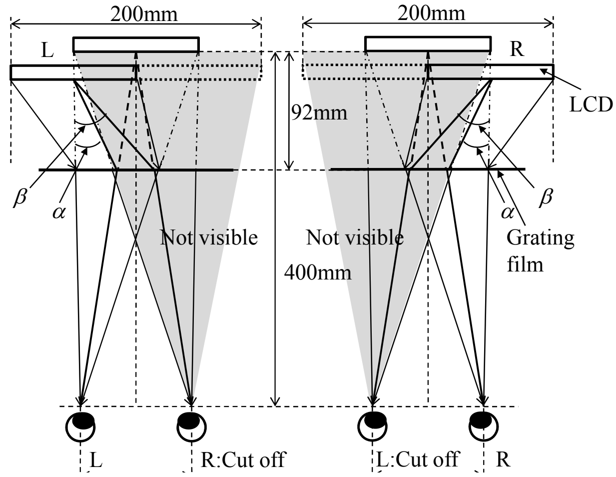


Fig. 18 Optical design for 3D viewing

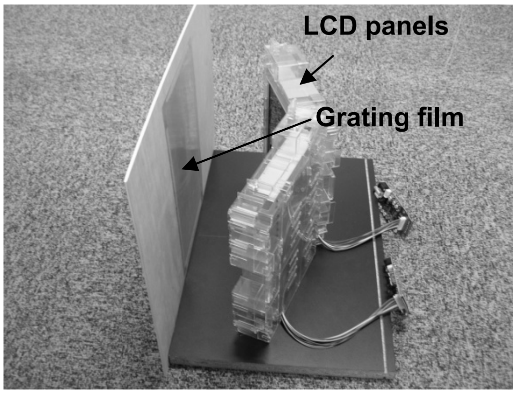


Fig. 19 Appearance of 3D display (KNA-30)

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