The Novel Patterned Retarder 3D Display with Wideband and Wide-view Circular Polarizer

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ABSTRACT

We present a novel patterned retarder configuration of stereoscopic 3D display which can show the wideband and wide-viewing angle to reduce the crosstalk in the vertical direction. We calculated the retardation of each film on a Poincaré sphere. We confirmed the reduced crosstalk of the proposed configuration in vertical direction.

1. Introduction

The technology of the displays has rapidly developed in order to satisfy viewer's requirements. In particular, recently many people began to want display which feels the three-dimensional (3D) effect over the two-dimensional (2D) flat image and the market for the 3D displays was increasingly expanded in the world. Many researchers have made an effort to develop new 3D technologies to satisfy customer's requests such as comfortable 3D image, 2D/3D switching, high brightness and resolution [1]. The 3D technologies are classified into two major categories of glasses and non-glasses types. Although the non-glasses type does not need glasses, the viewers feel uncomfortable due to a fixed viewing position [2]. On the other hand, the glasses type does not have any positional requirement and therefore guarantees watching the 3D image to many people in one place.

The kinds of the 3D display with glasses are anaglyph type, shutter glasses type and patterned retarder (PR) type [3-5]. Among the various glasses type 3D displays, the PR 3D display using the polarization glasses sends the left and right images to the eyes of a viewer simultaneously. This type has more advantages than the other 3D display with glasses, for example, higher brightness, lighter weight of the glasses and flicker free. However, this type uses retardation films which are manufactured by reactive mesogen (RM) materials in order to divide the left and right image. In general, the retardation film not only has properties in oblique direction such as the change of the optical axis and the phase retardation but also can cause the color difference due to the wavelength dispersion. Because of the drawbacks for the PR films, the quality of the 3D images is deteriorated and the crosstalk which is an overlap of the left and right image occurs.

In this paper, we proposed the novel PR configuration of circular polarization type to satisfy the both the wideband and wide-viewing angle requirements in vertical direction (the polar angle θ = 70° and the azimuth angle φ = 90°). The proposed optical configuration is composed of a $\lambda/2$ biaxial film, a $\lambda/4$ patterned film and a positive *C*-plate. The calculation of the optical structure has been performed on the Poincare sphere in the entire visible wavelength range using the Stokes vector and the Mueller matrix method. In order to verify the optical characteristics of the proposed configuration, we compared the light leakage and the crosstalk with the conventional configuration.

2. Design of wide-band and wide-view patterned retarder configuration

2.1 Conventional configuration

In general, the PR type of the stereoscopic 3D display uses the circular polarizer to divide left and right image because the use of a linear polarizer easily can cause the dizziness from light leakage when viewers rotate their heads. As shown in Figure 1(a), the conventional configuration of the PR 3D display comprises a linear polarizer and $\lambda/4$ patterned film of the positive *A*-plate property [6].

Figure 1(b) and (c) show why the change of the polarization states of the left and right light happens in vertical direction on the Poincaré sphere. And the symbols ○, □ and △ separately express the polarization state of the light with blue (*B* = 450 nm), green (*G* = 550 nm), and red wavelengths (*R* = 630 nm). As shown Figure 1(b), in the normal direction, the start position of the conventional configuration is position $-S_1$ when the light passes through the polarizer. Then, the light after passing through the left and right $\lambda/4$ patterned film rotate to the positions $L_{i\,(i=r,\,g,\,b)}$ and $R_{i\,(i=r,\,g,\,b)}$ from $-S_1$ as much as the retardation of the $\lambda/4$ film respectively. Here, a green wavelength obtains an excellent circular polarization states, on the other hand, the blue and red wavelength is elliptical polarization state because PR film has the positive wavelength dispersion properties. In the oblique direction (θ=70° and φ=90°), we can see more serious drawbacks. The Figure 1(c) shows that the optical axis of the left and right patterned film deviated to position A and B from $-S_2$ and S_2 with deviation angle δ in vertical direction [7]. Thus, we can confirm that the final polarization positions P_1 and P_2 after passing through the divided patterned film to the left and right considerably deviate from a circle S_1-S_3 due to the change of the phase retardations and optical axes of the PR film in oblique viewing angle.

As a result, a conventional optical configuration will show many residual images to the viewers wearing glasses which are made by using a $\lambda/4$ plate due to the deficient separation of two images which is caused by the color difference and change of the phase retardation and optical axis of the $\lambda/4$ patterned film.

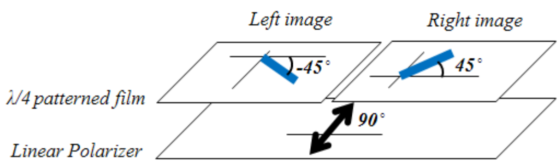

Fig. 1(a)

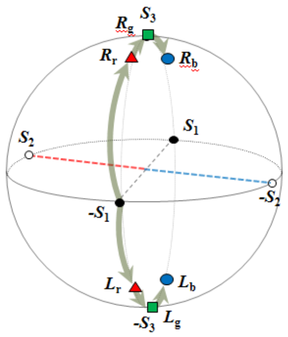

Fig. 1(b)

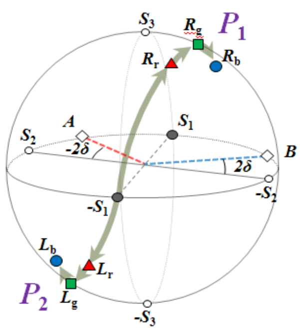

Fig. 1(c)

Fig. 1. (a) Configuration of conventional patterned retarder. Polarization states of the light on the Poincaré sphere for (b) the normal direction (θ=0° and φ=0°) (c) and the vertical direction (θ=70° and φ=90°)

2.2 Proposed configuration

To completely separate the two images into left and right handed circular polarization state in the entire visible wavelength at normal and oblique direction, we have attached a $\lambda/2$ biaxial film with $N_z \approx 0.5$ on the linear polarizer and added the positive C-plate on the $\lambda/4$ patterned film, as illustrated in Figure 2(a).

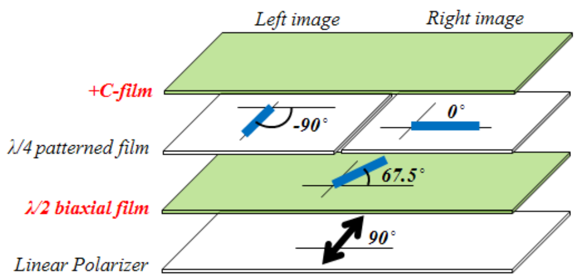

Fig. 2(a)

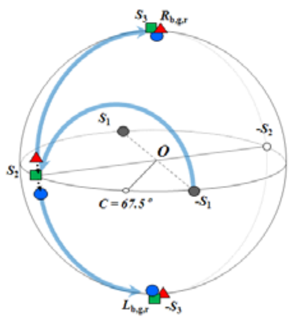

Fig. 2(b)

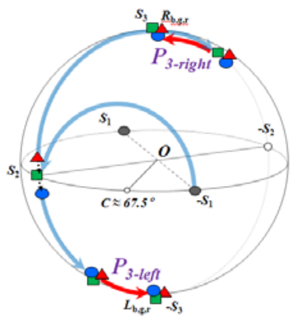

Fig. 2(c)

Fig. 2. (a) Configuration of proposed patterned retarder. Polarization states of the light on the Poincaré sphere for (b) the normal direction (θ=0° and φ=0°) (c) and the vertical direction (θ=70° and φ=90°)

Because this configuration can have the wide-band and wide-view property, first of all, the optical axes of the two films except a positive C-plate satisfy the following relationship [8]:

$$2\varphi_{\lambda/4} - 4\varphi_{\lambda/2} = \pm 90° \quad (1)$$

where $\varphi_{\lambda/2}$ is the optical axis of a biaxial λ/2 film, and $\varphi_{\lambda/4}$ is for the λ/4 patterned film. We chosen that the optical axis $\varphi_{\lambda/2}$ of the common part is 67.5° (position C) and $\varphi_{\lambda/4}$ of the left and right pattern is -90° and 0° (position S_1 and $-S_1$), respectively. Figure 2(b) depicts the polarization state trace on the Poincaré sphere when a light passes through the novel PR configuration at a normal direction. The incident light from the vertical linear polarizer is first rotated 67.5° from position $-S_1$ to another polarization states at position S_2 by a $\lambda/2$ biaxial film, then it is converted by the $\lambda/4$ patterned film which has the optical axes at position S_1 and $-S_1$ to position $\pm S_3$ of a circular polarization states for the full visual range. As a result, in comparison with a conventional configuration of the PR 3D display, we can obtain excellent separation of the left and right image for the entire wavelengths at the normal direction. Beside, this configuration is moving to complete right and left handed circular polarization position at oblique direction (θ=70° and φ=90°). As shown Figure 2(c), the polarization path(blue line) of the light after passing through the $\lambda/2$ biaxial film and $\lambda/4$ patterned film move in the same direction in common with normal viewing angle because the optical axes of each films is never deviated in oblique direction. By changing the retardation value of the film in oblique direction, However, we optimized the polarization states of the left and right image to the position $\pm S_3$ along the polarization path P_3 (red line) by using the positive *C*-film. In order to obtain the excellent circular polarization states of the divided two lights on the Poincaré sphere in the oblique direction, following two conditions for the polarization of the light are applied. The first condition is that the optical axis of the $\lambda/4$ patterned film must be equal to the oblique viewing angle (φ=90°) which is our target because deviation angle not occur. The second condition is that The N_z factor which represents $(n_x - n_z)/(n_x - n_y)$ of the $\lambda/2$ biaxial film must use 0.5 value. There are characteristics which almost has not deviation angle δ in oblique direction as well as normal direction when the N_z factor value is 0.5 [9]. Through the two conditions, we can design the configuration which has outstanding 3D effect in oblique direction.

3. Results and discussion

In general, the PR type in the stereoscopic 3D display provides the left and right images to the eyes of a viewer wearing the polarization glasses simultaneously because it is the passive retarder type. This type 3D display can cause the crosstalk which is called the ghost image when the polarized light after passing through the PR panel is transmitted to the each opposite eye wearing the polarization glasses. Thus, Figure 3 compares the simulated light leakage of the conventional and proposed configuration for the left and right image which pass through the opposite polarization glasses in vertical direction with polar angel θ = 70°. We observed that the proposed configuration showed excellent dark states for the entire visible wavelength range. This means final polarization states passing through the proposed structure move completely left and right handed circular polarization state.

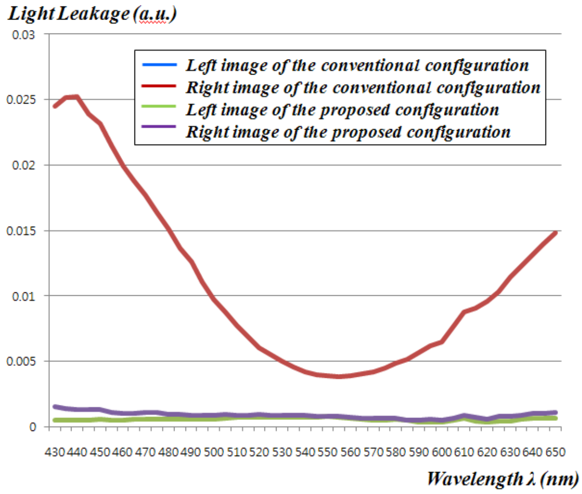

Fig. 3. Comparison of the light leakage for the conventional and proposed configuration in vertical direction (θ=70° and φ=90°)

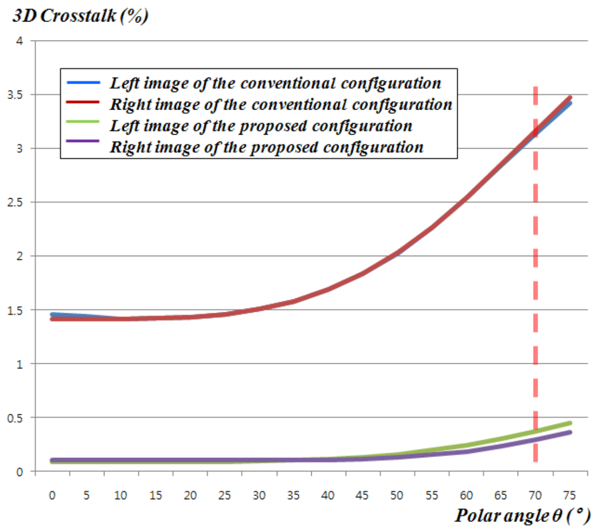

Fig. 4. Comparison of the calculated 3D crosstalk of the conventional and proposed configuration for the left and right image

Figure 4 compares the calculated crosstalk of the proposed configuration with that of the conventional in the vertical direction. We define the crosstalk value as below [10],

$$3D\ Crosstalk_{Left(Right)} = \frac{R(L)\_dark}{L(R)\_bright} \times 100\ [\%] \quad (2)$$

Here, *L(R)_bright* means the luminance of the left and right eye at the bright states. *R(L)_dark* is the luminance of the right and left eye at the dark states. From the calculated results, we can reduce the crosstalk of the proposed configuration in vertical direction (Left eye: 0.37% and Right eye: 0.29%).

4. Conclusion

In this study, we suggested a novel optical configuration of the PR film with wide-band and wide-view requirements by using a biaxial $\lambda/2$ film, patterned $\lambda/4$ patterned film which has the positive *A*-plate property and a positive *C*-plate. We simultaneously achieved the wide-band property and wide viewing angle characteristics through optimized design of the proposed optical configuration in the entire visible range. From the calculation, we confirmed that the 3D crosstalk diminished in vertical direction (Left eye: 0.37% and Right eye: 0.29%). Thus, we believe that the proposed optical configuration of the PR film can be applied to the stereoscopic 3D display using the patterned retarder type that require an outstanding 3D image quality and wide-view properties.

5. Acknowledgement

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6. References

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