Novel Diffuser Plate for Slim LCD-TV

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Abstract

Lamp mura has become a challenge for slim LCD-TV backlight design. The aim of this paper is to apply a novel diffuser plate to improve lamp mura issue instead of increasing lamps or optical films. The results are positive and contribute to the design of slimmer TV without cost up.

1. Introduction

Large LCD-TV market is growing rapidly and consumers demand for lighter and slimmer products. Therefore, how to develop a thinner LCD-TV has become an important subject. [1] Although there are many factors that contribute to the thickness of a LCD-TV, the depth of the backlight unit (BLU) is appeared to be a major factor and is widely studied. Nevertheless, many that have studied to slim the depth of the BLU have faced the lamp mura issue. Normally, people solve lamp mura issue by adding the number of lamps or optical films or add prism between lamps[2], which results in the high cost.

Lamp Mura is a phenomenon caused by the uniformity of the lamp luminance. This is because the region on the top of the lamp is brighter while that between the lamps is darker. Thus, there are many bright and dark bands appeared on the diffuser plate, as shown in Fig. 1.

Fig. 1. Lamp Mura In Direct BLU

Conventionally, the LCD-TV BLU is constructed by a lighting system and a light diffusing system. Lighting system includes a light source, such as lamps or LED light bars and brightness enhancement films, such as prism films. On the other hand, a light diffusing system is necessary to scatter the light from the lighting system and to spread the luminance uniformly in the BLU. Typically, a diffusing system includes a diffuser plate, which is made of plastic material in terms of PMMA, PC or MS[3], on which the scattering particles are spread. A standard direct BLU configuration is showed as Fig.2.

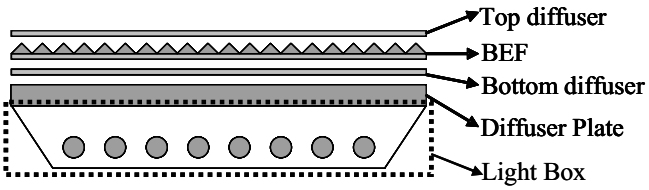


Fig. 2. Standard Normal Direct BLU Structure

Generally, lamp mura can be improved by enlarging the distance of the lighting system but this is against the goal of the slim design. Normally, people solve lamp mura issue either by adding more lamps to narrow the gap between the lamps or by increasing optical films to cover the dark bands. However, any of them not only increases the thickness of the backlight unit but also increases the cost.

In this paper, we apply a dot pattern distribution on the diffuser plate [4] to make the luminance spreading uniformly. Moreover, a prism pattern is also added to this distribution to overcome the lamp mura issue. By this method, slim design is achievable and lamp mura is improved without any cost added.

2. Simulation

Firstly, a dot pattern distribution is printed on the diffuser plate. Furthermore, a prism pattern is added to achieve a good uniformity of the

luminance.

2.1 Reflecting Dot Pattern Distribution

Fig.3 indicates the optical simulation results of two lamps. The brightness shape of two lamps is a curve, which is similar to the Gaussian distribution. The peak means the place that radiates more and appears to be brighter; on the contrary, the trough is the place that radiates less and appears to be darker. What we attempt to do is to find out a dot pattern distribution and to print it on the diffuser plate, which is able to uniform the peak and trough places as well as to alleviate lamp mura.

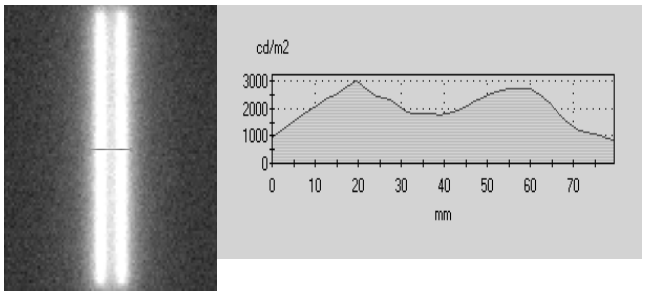


Fig. 3. Optical Simulation Result

Firstly, we distribute the density of the dot pattern depending on its brightness curve, which can be seen in Fig.4. The distribution of the density is divided into several areas and each of them (ΔA') is integrated.

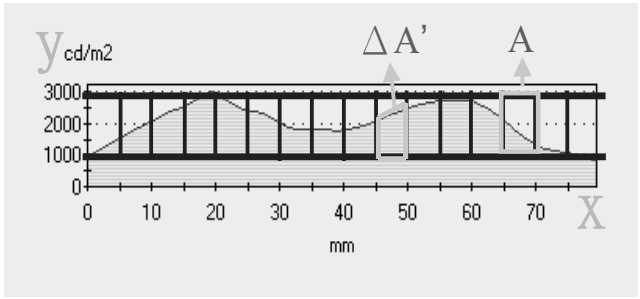


Fig. 4. Area Integration

The density is counted by the following equation

$$\Delta A' = \int y dx \qquad \text{Density} = \Delta A'/A \quad (1)$$

According to the equation, we set up a distribution, of which the peak places have more dots to reflect the light while the trough places have few dots to let straight lights go through so that the brightness curve is able to be uniformed. The dot pattern distribution is printed on the diffuser plate as shown in Fig.5.

Through the reflection of the printing dot pattern, the luminance is redistributed within the backlight and lamp mura is alleviated.

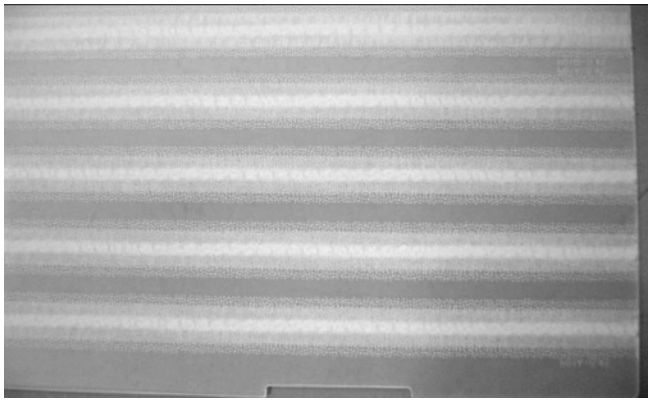


Fig. 5. Dot Pattern On Diffuser Plate

Nevertheless, the optical simulation result of the diffuser plate with the printing dot pattern still illustrates that there are some dark bands between the lamps. (Fig.6) In addition, it is found that the uniformity is accepted by human eyes when it is above 70% in our simulation. But the uniformity of the diffuser plate with the printing dot pattern is only 45%. Thus, we need to find out other methods to cover the dark bands.

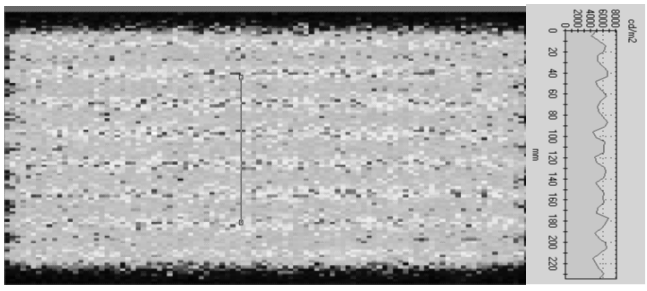


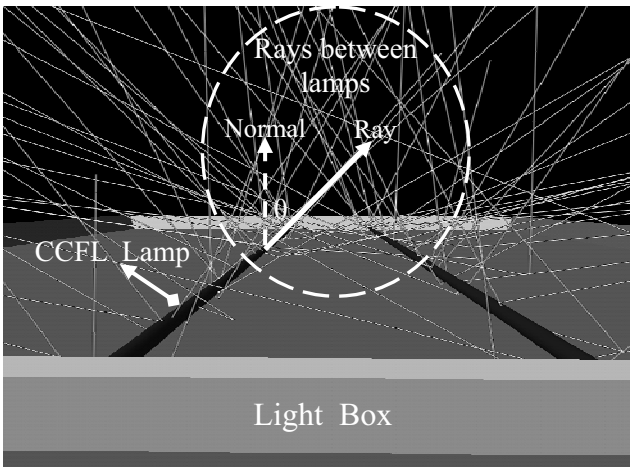
Fig. 6. Optical Simulation Result Of Dot Pattern

2.2 Prism On Top Surface Of Diffuser Plate

Because of factor $\cos\theta$, from the luminance definition equation(2),. Observer will receive less luminance between lamps than top. So we need to find out some way to reduce the value of $\cos\theta$. (Fig.5).

The luminance definition equation is shown as follows:

$$\text{luminance} = \frac{dI}{dA} * \cos\theta \quad (2)[4]$$



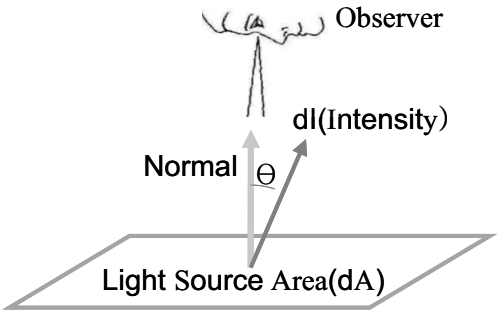


Fig. 7. Light Rays Between Two Lamps

Based on our simulation result, the prism structure has proved to fulfill this task (Fig.8). Prism structure has good performance to make rays normal to observer (Fig.8).

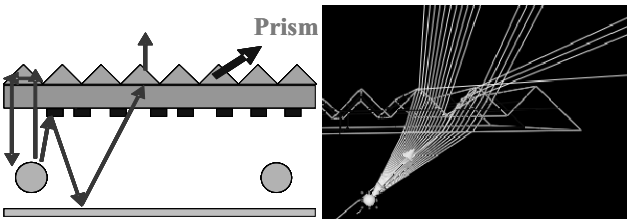
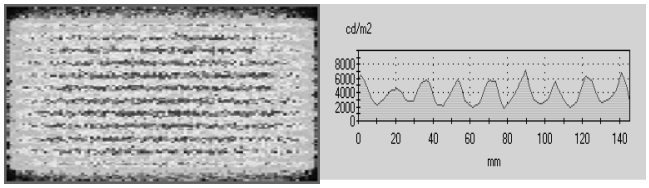


Fig. 8. Diffuser Plate With Prism

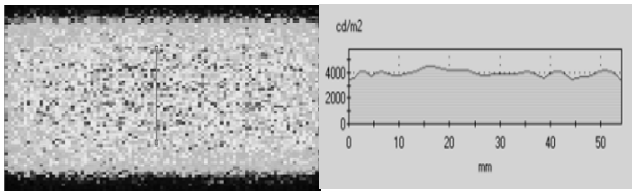
By this prism combined with dot pattern structure, the straight light rays from the top of lamps refracted by prism structure and dot pattern, and the oblique rays between lamps corrected to normal(Fig.8).

3. Results and discussion

The luminance uniformity of the backlight using the conventional diffuser plate and the new diffuser plate are shown in Fig. 9. A backlight using only a conventional diffuser plate causes serious Lamp Mura. It is difficult to come to good uniformity of the backlight. However, Fig. 9(b) confirms that good luminance uniformity is obtained by using the Novel Diffuser Plate. This luminance uniformity is achieved by optimizing the structure of the diffuser plate.



a. Conventional Diffuser Plate



b. Novel Diffuser Plate

Fig. 9. Simulation Result Comparison

TABLE 1. Uniformity Comparison

Diffuser Type	Uniformity
Diffuser Only	15%
Diffuser + Dot Pattern	45%
Diffuser + Dot + Prism	76%

As Table.1 shows, the Novel Diffuser Plate with dot pattern and prism structure is able to increase the uniformity obviously.

These results indicate that in the BLU using newly developed diffuser plate structure, the light from the lamps is distributed uniformly. It allows us to reduce thickness of the backlight module effectively. Further more, the price of large size LCD-TV continues to fall, and excessive supply causes pricing pressure on the panel suppliers. In order to reduce system cost, we remove three optical films from the normal 32-inch BLU as shown in Fig.2, and successfully solve the Lamp Mura problem.

4. Summary

This Novel Diffuser Plate is designed to improve

the Lamp Mura. We verified that the prism structure combined with dot pattern on the diffuser plate help the light from lamps to distribute uniformly. The uniformity is from 15% up to 76% in simulation. That allows thinner easier design of direct TV Backlight, and reduces the optical films to achieve the goal of cost down.

5. References

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