The Analysis of the Optical Characteristics for the Optimum Design of the Direct type BackLight-Unit

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Abstract
We focused on improving of the optical efficiency in the direct BLU. We could achieve the optical efficiency by reducing the thickness of BLU and processing the prism shapes on a reflection sheet. And we were able to reduce the Lamps.

1. Objectives and Background
TFT-LCD requires the Light Source because it doesn't light by itself. Herein a BackLight Unit performs a role of Light source of TFT-LCD. BLU is composed of Lamps, Light Guide plate, optical sheets. BLU is divided by the position of the Light source and the LGP's shape. It is classified to Side type and direct type by the position of Light source. And it is classified to Wedge type and flat type by the shape of LGP. In Size of products, BLU of Side and Wedge type is used in below 15inch Note PC. Side and flat type BLU is used in below 20inch Monitor and Direct type BLU is used in beyond 20inch TV. Any BLU is expected to improve the optical efficiency so that we need to design the optimum conditions of BLU. We have aims how much brighter we make, how to reduce the thickness of BLU, how to have a competitive price. Herein, Recent BLU is reflecting this tendency. So we focused on improving of optical efficiency in BLU of direct type. The main parts of direct type BLU are reflection sheet, lamps, diffuser plate, and optical sheets. The main factors of design are lamp number, lamp pitch, lamp height, distance between reflection sheet and diffuser plate. In this experiment, we select the distance between reflection sheet and diffuser plate and a processed shape as main factor for improving the optical efficiency. We have known that a processed shape effects the improvement of uniformity by simulation. Based on this simulation result, we made samples reduced the thickness of BLU for raising the brightness and processed shapes on reflection sheet for making good of uniformity. Also we reduced the lamp number in considering that the brightness will be improved. Samples were made by the optical simulation results.

2. Results
2.1 Experiment conditions
BLU used in Experiment was made up 16 lamps, reflection sheet, diffuser plate, 3 diffuser sheets. The type is the 32inch direct type BLU. Design factor of the sample BLU are below.

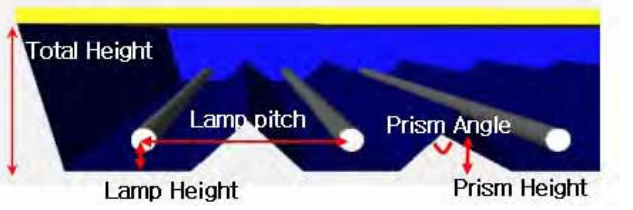

Figure 1.<Design conditions>

The Base conception of this experiment is the raise of brightness and improvement of surface grade by reducing of thickness as well as processing shapes. We could be comparable the tendency that reflection sheet' shape is or not by ray tracing with simulation.

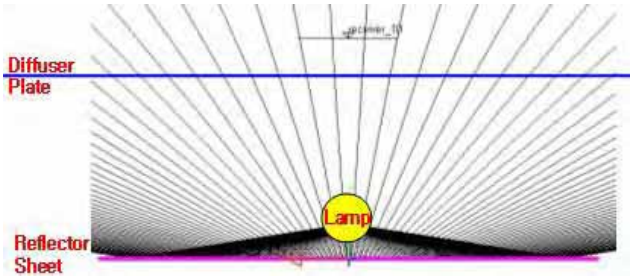

Figure 2 < The Ray tracing on no shape>

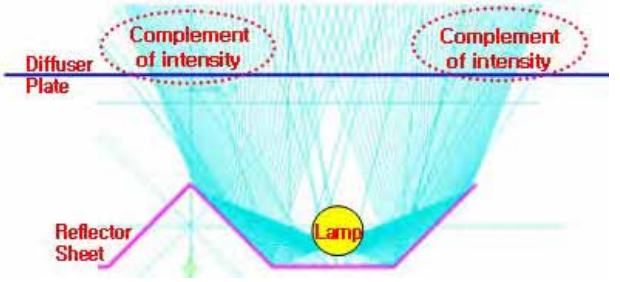

Figure 3 < The Ray tracing on prism shape>

The Figure 2 and 3 are shown the difference of two types. If we have the processed shape between lamps, shapes complement the intensity of the point above the shape. Then we will achieve the raise of brightness. The following Figure is a whole view of the processed reflection sheet.

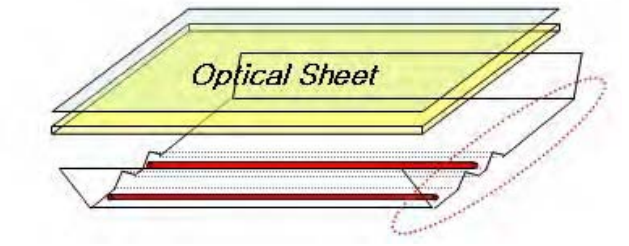

Figure 4 < Whole View>

2.2 First experiment

First, we reduced the thickness of the total Height for improving brightness. To review of brightness in surface of BLU according to reduction of the thickness, we measured a brightness distribution of surface in changing the total height. We settled a condition of BLU under a qualification of 16 lamps and same lamp height while only lowered the height of the diffuser plate.

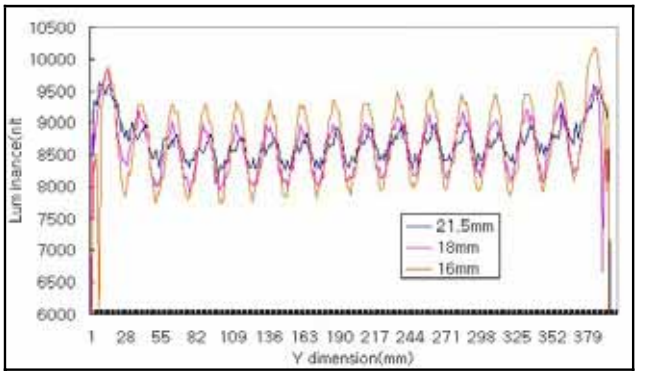

Figure 5 < Line scanning of surface for lowered total Height >

If reduce the total height, lamp is relatively more close to the diffuser plate. So that cause the lack of surface uniformity made with Light area and dark area as a lamp shape. Herein, the processed prism shapes make up the brightness gap between light area and dark area. There again, we name the lack of brightness of the surface uniformity caused by a light area and a dark area for Luminance Mura. We could raise the Brightness and Uniformity in making them on reflection sheet. The processed prism shapes have an important role which complements the uniformity. If Luminance Mura is bad, the quality of surface of product is bad. Therefore we have to consider that. First of all, 1st sample reduced the 2 lamps. Simulation result of luminance by reducing the 2 lamps is below. We fixed the total height with 18mm and average luminance isn't compensated with real measurements.

	Lamp number	Average Luminance
Case 1	16	2202
Case 2	14	1921
Relative Comparison	14/16=0.875	0.872

Table 1 < Simulation result of removing 2 lamps>

In this result, we expected luminance will be lower about 12~15% when reduce the lamp number from 16 to 14. We decided lamp pitch as 27.5mm is better than others in simulation result. Table 3 shows the simulation result of prism angle of shapes improved the brightness. Prism height is settled with 7.0mm.

Prism angle	60°	90°	110°	120°
Average luminance	1946	1965	1960	1950
Relative comparison	1.013	1.022	1.020	1.015

Table 2 < Simulation result according to the change of a prism angle of the shape>

This result isn't compensated too. Based on this result, we will design the BLU which have the luminance downed about 5%. Decrease in luminance about 15% caused by reducing the lamp number can be offset by the increase in luminance caused by processed shapes. In result, we achieved the 8534nits of center luminance and 97% of uniformity of 5points. Luminance of the first sample was raiser than the base BLU about 5%. But Luminance Mura is bad. To review the Mura, we measured the surface Luminance. Below figure shows the scanning luminance of Y dimension of surface of BLU.

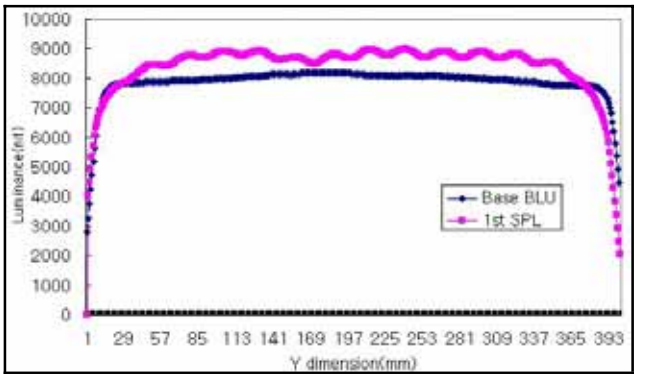

Figure 6 < Line scanning of surface luminance of 1st sample>

Luminance Mura is strongly shown, because lamp is relatively close to diffuser plate. We didn't move the lamp height, only change the total height. Based on this result, second sample was made up luminance Mura.

2.3 Second experiment

2nd sample was focused on improvement of quality in surface luminance. We thought Mura is caused by lamp closed to the diffuser plate. So we changed the lamp height, compared the result of surface of Luminance in small area by simulation.

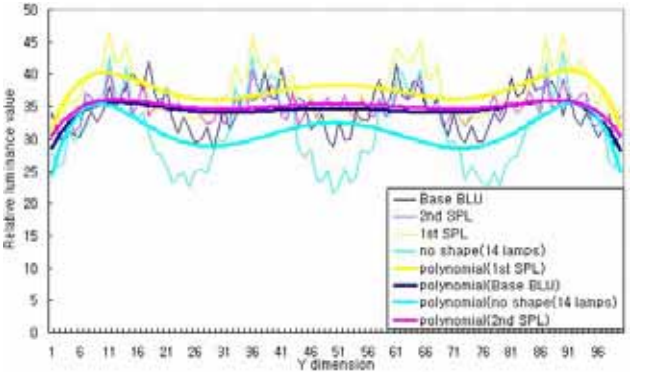

Figure 7 < Simulation result according to the change of the lamp height >

In this result, we could know that if we lower lamp height, we could have a same level to the base BLU. We made a 2nd sample based on simulation results and achieved the 7783nits of luminance in center, 94% of uniformity of 5points by lowering the height of lamp. It decreased only about 5% of luminance although 2 lamps were reduced.

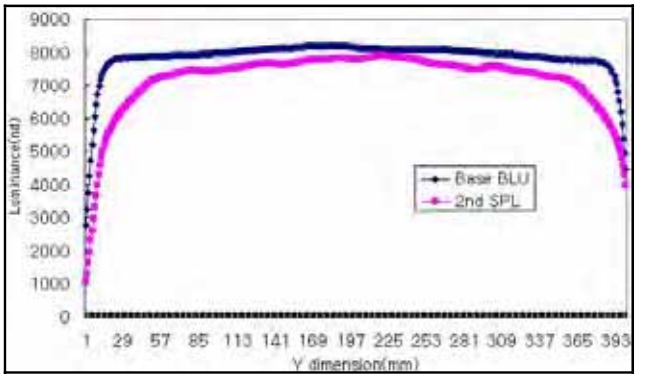

Figure 8 < Line scanning of surface luminance of 2nd sample>

In Line scanning result, we got an improved quality of the surface luminance.

2.4 Summary

As we had expected, we could have effects of the raising the luminance and improving the uniformity or luminance Mura by reducing the thickness of BLU and processing the prism shape on reflection sheet. And we could improve the luminance Mura in relatively lowering the height of lamps caused by closing to the diffuser plate. We summarized conditions and results of BLU we made.

	The Base BLU	1st sample	2nd sample
The existence of shape	-	Prism shape	Prism shape
Lamp number	16ea	14ea	14ea
Prism Height	-	7.0mm	7.0mm
Prism Angle	-	90°	90°
Center Brightness	8171nits	8534nits	7783nits
Uniformity (5point)	97%	97%	94%

Table 3 < Design factor and results of BLU we made>

Figure 9 < Real image >

3. Impact

In this paper, we could improve the optical efficiency of the direct type BLU by reducing the thickness of BLU and processing the prism shape on reflection sheet to raise the brightness and to improve the uniformity. We changed the conditions of base BLU had 16 lamps. First, we reduced the total height of 4mm, which is a gap between reflection sheet and diffuser plate. And then we processed the prism shape decided by the simulation result on reflection sheet. Last, we lowered the height of the lamp for improving luminance Mura. Eventually, we could achieve the raising the Brightness. In using this result, we can have a competitive price by removing the 2 lamps as compared with the base BLU. We had expected that the brightness of BLU used 14 lamps decreases about 12~15% as compared the base BLU used 16 lamps. But we have only a decrease of brightness about 5% due to change of this experiment conditions. Consequently, we will have a competitive position.

4. References

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