Monolithic Light-Guide Plate with Prism Structure for 1.5D 32 Dimming Zones and Narrow Border LCD

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ABSTRACT
We have developed monolithic functional LGP (PMMA-LGP) for LCD backlight unit (BLU) with prism structure enabling 1D or 1.5D segment dimming. We simulated and optimized the prismatic PMMA-LGP, confirming the 1.5D dimming and light collimating characteristics of the initial sample. We have succeeded in build-in prism structure on 15.6" PMMA- LGP and there are two kind of collimating LGP(one is deeper than conventional structure and the other is aggressive one).Both are defined by the dimming factor m and η to describe the collimating property. Finally, the 15.6" sample property include 1.5D segment dimming with 32 zones, the VESA STANDAREDER (border U/L/R 3.25mm) , 4K Display HDR600[1] & DCI-P3(u'v') >90% min coverage and the contrast 140,000:1 at least.

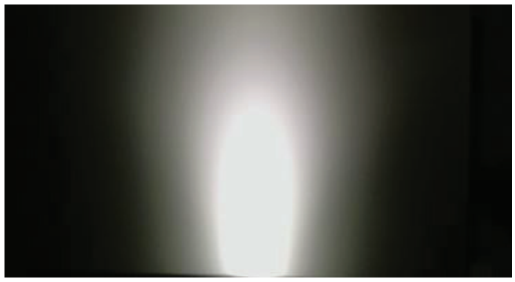
1. INTRODUCTION
The VESA High-performance Display Compliance Test Specification (Display HDR CTS), the image quality parameter values for high dynamic range for use in production and international program that defines peak luminance of HDR400, HDR600, HDR100 for display [1]. Since a high brightness is mandatory for 4K Display, high performance backlight units (BLUs) are important. Besides, The contrast parameter values are defined in the spec..

In recent production, BLUs with prismatic LGPs for Laptop sets are in the market. By designing prismatic structure on the LGP and LED (light emitting diode) LB (Light-bar) controlled by independent circuit, a high brightness BLU and local dimming 1D (one-dimension) can be achieved. With adding another LED-LB in opposite side, it shows 1.5D dimming property and benefit to picture quality than 1D. design.(In edge lit design,1.5 D means twice dimming zone compared to 1D) Furthermore, the 1D or 1.5D dimming technology can enhance the moving picture quality by controlling the white/black segment in each frame picture [2-4].

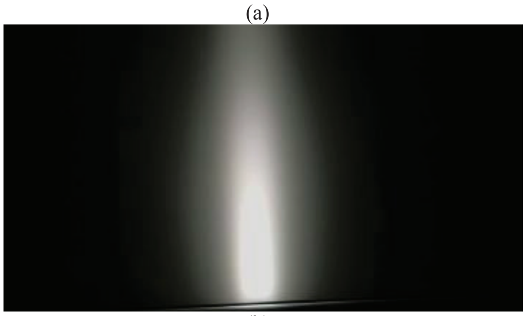
2. PRISMATIC DESIGN AND DIMMING DEFINITION
For prismatic structure, we have simulated two Recipes and look forward the collimating performance for our product. Fig. (1)It shows two kind of the distribution with one LED lit on. Recipe 1 is wider distribution compared to Recipe 2(Recipe1 is still narrow than conventional LGP design) Recipe 2 shows more narrow and collimating distribution. Due to collimating distribution would make LED Mura worse in the narrow border design, it's important to choose the suitable Recipe concerning collimating distribution and VESA narrow border U/L/R 3.25 mm requirement.

Simulation	Dimming Performance
Prism Recipe 1	
Prism Recipe 2	

Figure (1) Simulation for prismatic LGP (2) Recipe 2 show more collimated distribution than Recipe1.



(a)



(b)

Figure (2)(a) Prismatic-1 LGP (b) Prismatic-2 LGP .one segment lit on and both show different collimating performance

To distinguish the collimating performance Fig.(2), we define the two parameter value: **light diffusion ratio m for** horizontal level and **Light isolation ratio η** for vertical level

(1) Light diffusion ratio m
Slop m (24th zone) (Fig.3):
1. The Zone 24 lights on only (BLU divide into 32 zones)
2. Measure position at 1/4W and follow yellow line which each point distance is 5mm
3. Calculate the width Y1 (mm).at 50% Brightness (Fig.4)
4. Measure position 1/2W and along yellow line which each point distance is 5mm
5. Calculate the width Y2 (mm).at 50% Brightness
6. Record (1/4W, Y1), (1/2W,Y2).
7. Get Slop m (24) =4| Y2-Y1|/W

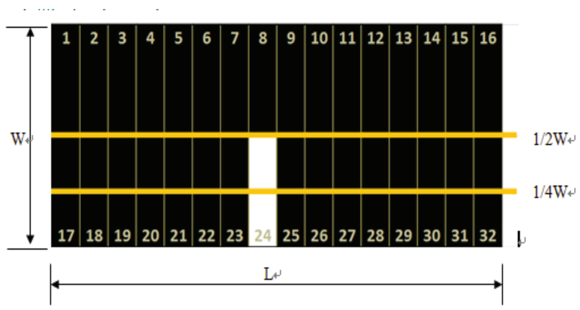


Figure (3) Total 32 Zones and define 24th at zone position W & L

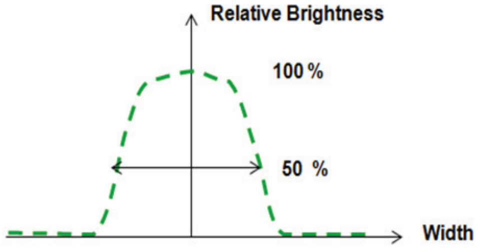


Figure (4) Define the one dimming Y1,Y2,Y3,Y4 width with FWHM

Slop m(8th zone) (Fig. 5):
1. The Zone 8 lights on only (BLU divide into 32 zones)
2. Measure position at 3/4W and follow yellow line which each point distance is 5mm
3. Calculate the width Y3(mm).at 50% Brightness (Fig.4)
4. Measure position 1/2W and along yellow line which each point distance is 5mm
5. Calculate the width Y4(mm).at 50% Brightness
6. Record (3/4W,Y3), (1/2W,Y4).
7. Get Slop m(24) =4| Y4-Y3|/W

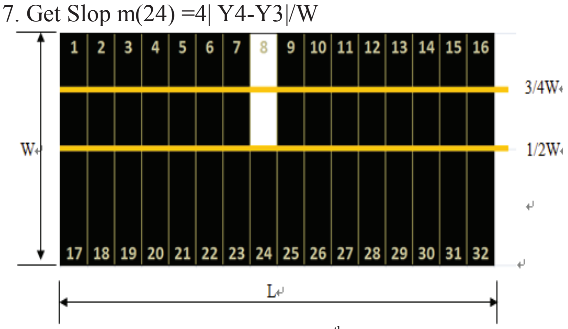


Figure (5) Total 32 Zones and define 8th at zone position W & L

(2) Light isolation ratio η
Ƞ(24th zone)(Fig.6):
1. The Zone 24 lights on only (BLU divide into 32 zones)
2. Measure position along the center line of zone 24 and from bottom zone 24 to Top zone 8 and each point distance is 5mm
3. (Fig.7) Calculate Ƞ(24)=(light leakage area)/(the ideal area)*100%

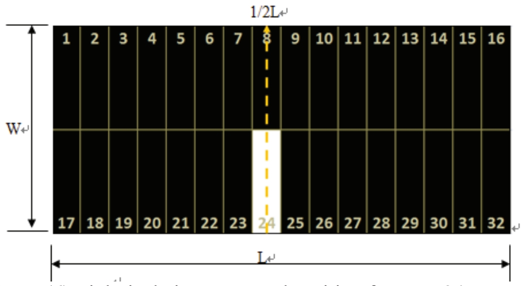


Figure (6) Light isolation measured position for zone 24

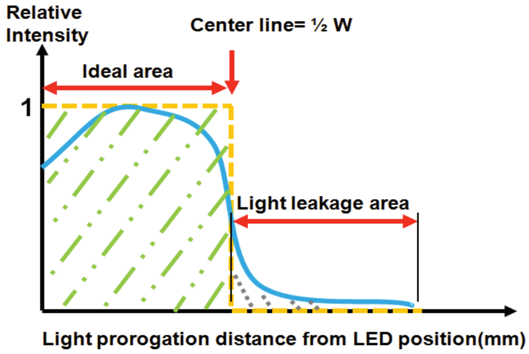


Figure (7) 1.5D Light isolation definition: light leakage/ideal area

Ƞ(8th zone) (Fig.8):
1. The Zone 8 lights on only (BLU divide into 32 zones)
2. Measure position along the center line of zone 24 and from Top zone 8 to bottom zone 24 and each point distance is 5mm
3. (Fig.7) Calculate Ƞ(8)=(light leakage area)/(the ideal area)*100%

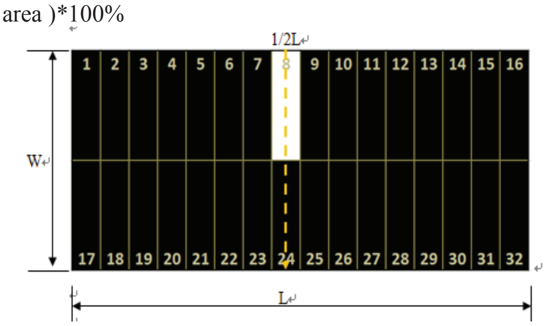


Figure (8) Light isolation measured position for zone 8

3. CONCLUSION

According to the DisplayHDR_CTS_v1.0(Table1), HDR 600 Luminance Specifications (Fig.9) (Fig10) and color gamut Specifications (Fig.11), we measure the corner white and center white to calculate the contrast 140,000:1 and Red ,Green, Blue pattern to calculate the DCI-P3 96%(Fig.12). In LGP collimated performance, we measure two types of LGP design, m 0.12, η 7.6% for normal design and m 0.03, η 20% for aggressive design. (Fig.13)

Table 1-1: DisplayHDR Performance Tier Summary [1]						
Tier	Minimumwhite Luminance Test – 10% Center Patch and Full-screen Flash Tests Minimum Requirement (cd/m2)a	Minimumwhite Luminance – Test Full-screen Long-duration Test Minimum Requirement (cd/m2)b	Corner Box Test – Black-level Test Maximum (cd/m2)c	Tunnel Test – Black-level Test Maximum (cd/m2)d	Minimum Color Gamut in CIE 1976 u', v' Format e	Minimum Bit Depthf
400	400	320	0.4	0.1	95% ITU-R BT.709	• 10-bit image processing in dimming processor • 8-bit driver IC
600	600	350	0.1	0.1	99% ITU-R BT.709 and 90% DCI-P3 D65 (SMPTE RP 431-2)	• 10-bit image processing in dimming processor • 8b + 2b dithering in display pipeline • 8-bit driver IC
1000	1000	600	0.05	0.1	99% ITU-R BT.709 and 90% DCI-P3 D65 (SMPTE RP 431-2)	• 10-bit image processing in dimming processor • 8b + 2b dithering in display pipeline • 8-bit driver IC

Table1 .DisplayHDR_CTS_v1.0 Specification Summary [1]

Figure (9) DisplayHDR_CTS_v1.0, Luminance Specifications -Center white [1]

Figure (10) DisplayHDR_CTS_v1.0, Luminance Specifications -Corner white[1]

Figure (11) DisplayHDR_CTS_v1.0, color gamut Specifications [1] R(**255**,0,0) , G(0,**255**,0) , B(0,0,**255**)

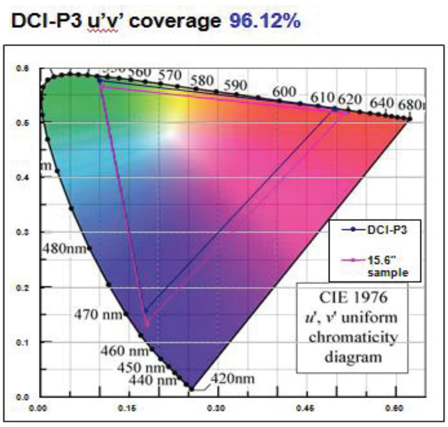


Figure (12) 15.6" module performance: DCI-P3 96%

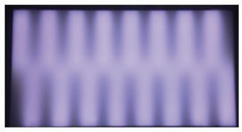
	Dimming factor		Dimming Performance
	m	η	
1st LGP tooling (normal)	0.12	7.6%	
2nd LGP tooling (aggressive)	0.03	20%	

Figure (13) 1.5D Dimming performance with **m** 0.03 and **η** 20% for aggressive design

We demonstrate a 15.6" module with 1.5D local dimming(Fig.14) (Fig.15) , with **m** 0.03 and **η** 20% , narrow border , 140,000:1 contrast ratio, HDR600 and DCI-P3 96% . In this result, the dimming factor **m** 0.03 is the extreme design for narrow border(R/U/L 3.25 mm). With the 1.5D local dimming technology, It can enhance the moving picture quality, better than 1D local dimming. This is the first worldwide product reporting a monolithic LGP with prismatic structure in 1.5D within narrow border 3.25mm.

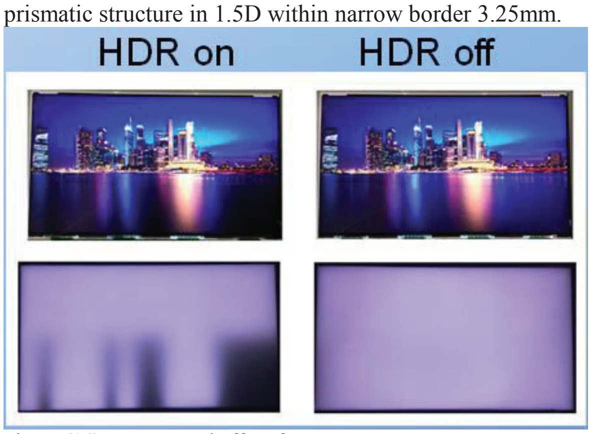


Figure (14) HDR on and off performance:
Top (Left & Right) show LCM image and Bottom (Left and Right) show dimming zone of back-light unit

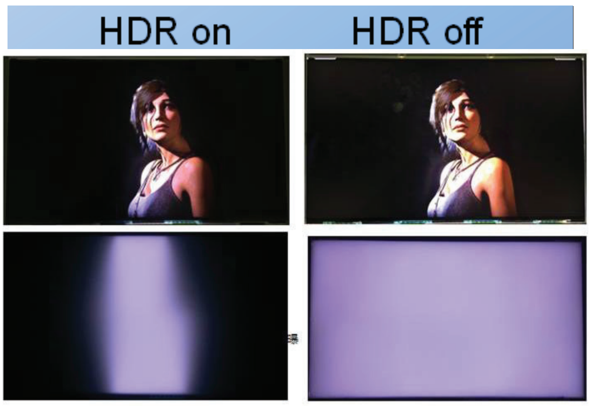


Figure (15) HDR on and off performance:
Top (Left & Right) show LCM image and Bottom (Left and Right) show dimming zone of back-light unit

5. REFERENCE

[1] DisplayHDR_CTS_v1.0

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