17.3-in Mini-LEDs Halo Effect and Human Factor Study for High-End Notebook Application

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ABSTRACT

Local dimming technology could increase contrast. Most of halo effect study is based on face-view. This paper would indicate performance and halo effect at different viewing angle. Finally, we proposed a 17.3-inch Mini-LEDs notebook module that can reach HDR1000 specification and less suffer from low contrast at different viewing angle.

1. INTRODUCTION

Display technology would push 8K broadcast for 2020 Tokyo Olympic. SDR specification (Standard dynamic range) is not enough for 4K display or 8K display. For higher user's experience, user wants high image quality that has more details. The new word, HDR (High dynamic range) appears that means the display could predict more contrast between brightest and darkest parts of an image.

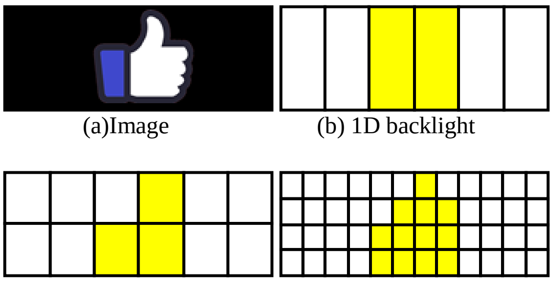
Figure (1) Different contrast image

There are lots of HDR standard in few years, like Dolby vision (Dolby), HDR10 (Consumer Technology Association), HDR 10 plus (Samsung and Amazon Video). In the end of 2017, VESA (Video Electronic Standard Association) announces first version of VESA's DisplayHDR standard, including HDR400/ HDR600/ HDR1000. In general, notebook user often uses the notebook in power saving mode that decreases the brightness to get more power endurance. In 2019 VESA adds a new 500 level to the Display HDR. HDR500 is close to HDR600 that difference is only maximum brightness. That lets notebook designer has more design specification to fit different customer requirement.

Table (1) DisplayHDR specification [1]

	SDR (cd/m^2)	HDR400 (cd/m^2)	HDR500 (cd/m^2)	HDR600 (cd/m^2)	HDR1000 (cd/m^2)
Min. Bri. (10% center)	250-300	400	500	600	1000
Min. Bri. (Full-screen flash)	250-300	400	500	600	1000
Min. Bri. (Full-screen long duration)	250-300	320	320	350	600
Max. Bri. (Corner)	0.5-0.6	0.4	0.1	0.1	0.05
Max. Bri. (Tunnel)	0.5-0.6	0.1			

By local dimming backlight, LCD (liquid crystal display) could reduce the power consumption and get HDR level performance. The panel with 1D/1.5D local dimming backlight could let display achieve HDR400/ HDR500/ HDR600 specification. For HDR 1000 standard, it needs to use 2D local dimming backlight to get higher dynamic range. Therefore, Mini-LEDs backlight is a better solution for some applications that must need slim module.



(a)Image (b) 1D backlight

(c) 1.5D backlight (d) 2D backlight

Figure (2) Local dimming technology

By rotating the orientation of liquid crystal molecule, LCD controls the pixel on/off to display image. Different viewing angle could see different polarization direction that let the LCD has limited viewing angle and makes LCD has lower contrast ratio at large viewing angle. Some application is for individual that doesn't need wide viewing angle, like notebook application. For some high-end notebook (gaming, painting), user wants image has more detail information. Therefore, we proposed a 17.3" Mini-LEDs NB module that could reach HDR1000 and less suffer from lower contrast at larger viewing angle.

2. Discussion

In general, notebook application doesn't need large viewing angle. For better user experience, user may not accept evident lower contrast and worse image quality at large viewing angle. And some high-end notebook has larger display size, like gaming. Assuming the distance from notebook to user is 400mm, user sees the edge of notebook has larger viewing angle with larger size notebook. The viewing angle increases around 5.8° at horizontal/ diagonal direction and around 2.4° at vertical direction from 13.3 inch notebook to 17.3 inch notebook. For some user (developer, gamer…), they even use two or more monitor. Assuming the distance from notebook to user is 400mm, user sees the edge of notebook has larger viewing angle with larger size notebook. The viewing angle increases around 8.1° at horizontal direction and around 4.1° at vertical direction and around 7.5° at diagonal direction from 13.3 inch notebook to 17.3 inch notebook. Most of high-end product of notebook has larger size display that means user would have more possibility to see the display at larger viewing angle with high end notebook. The larger viewing angle causes the lower contrast that could be solved by local dimming function. But the local dimming could not avoid halo effect. If the contrast of panel decreases, the halo effect will become evident.

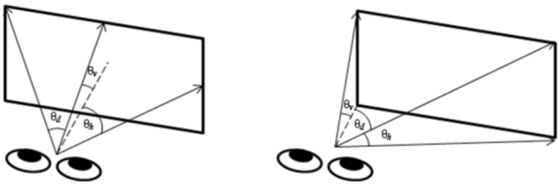


Figure (3) Different viewing angle

Table (2) Viewing angle at corner

Center	x (mm)	y (mm)	Horizontal	Vertical	Diagonal
13.3-inch	286.1	178.8	19.7 °	12.6 °	22.9 °
14.0-inch	309.4	174.0	21.1 °	12.3 °	23.9 °
15.6-inch	344.2	193.6	23.3 °	13.6 °	26.3 °
17.3-inch	381.9	214.8	25.5 °	15.0 °	28.7 °
Edge	**x (mm)**	**y (mm)**	**Horizontal**	**Vertical**	**Diagonal**
13.3-inch	286.1	178.8	35.6 °	24.1 °	40.1 °
14.0-inch	309.4	174.0	37.7 °	23.5 °	41.6 °
15.6-inch	344.2	193.6	40.7 °	25.8 °	44.6 °
17.3-inch	381.9	214.8	43.7 °	28.2 °	47.6 °

In our experiment, the halo effect is more evident at large viewing angle than face-view in 17.3" mini-LEDs module. It affects image quality at large viewing angle. And it would be more serious, if the user uses larger display or two displays.

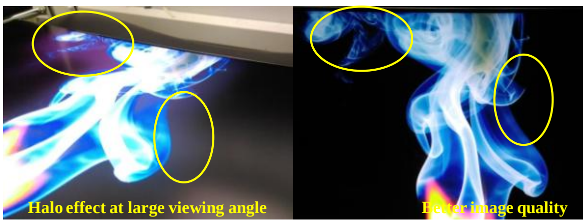


Figure (4) Display quality comparison at different viewing angle

3. Result

We demonstrate a 17.3-inch notebook Mini-LEDs module with HDR1000 specification. At face-view, the image quality of both displays is nearly the same. At the larger viewing angle, the contrast of normal structure module becomes worse. It let the halo effect evident and worse image quality.

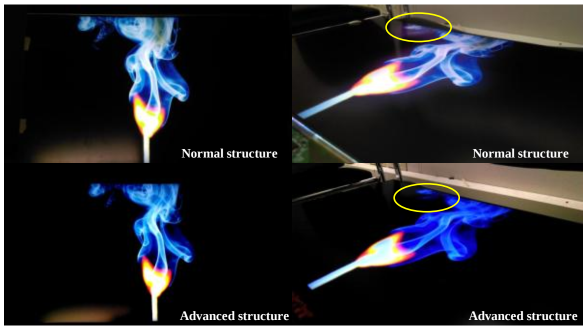
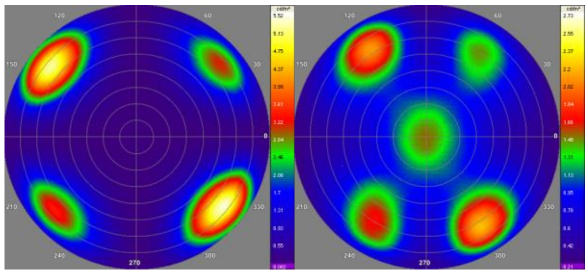
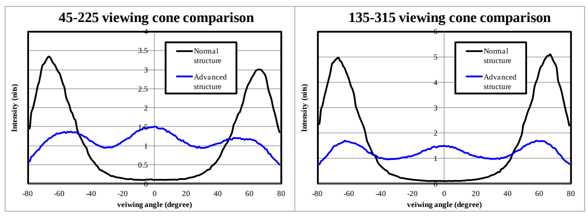


Figure (5) Image performance comparison at different viewing angle

For the better uniformity and white pattern quality, the backlight local dimming zone is not perfect rectangular shape that light would spread to the other surrounding dimming zone. It's because of that, the detail between dark and bright would be affect by the halo effect become worse image quality. We measure the viewing cone at dark state (L0) without local dimming function that is easier to observe the light leakage at dark state. At large viewing angle, the light leakage intensity of normal structure module is two times more than advanced structure one and the suffered area of normal structure module is larger than advanced structure one. But the advanced structure module would suffer the light leakage at face-view. It's easy to solve it when turning on the local dimming function.



(a) Normal structure (b) Advanced structure



(c) 135-315 profile (b) 45-225 profile

Figure (6) Viewing cone at black pattern (L0)

In notebook application, the length of horizontal is longer than the length of vertical, as 15.6-inch notebook, the aspect ratio is 16:9. Therefore, the light leakage at dark state is not easier to be observed at higher φ angle. Therefore, we could hide the light leakage area at higher φ angle. It lets user not easy to see the light leakage at larger viewing angle. It means that well-design could have better image quality in most of user's situation. In our experiment, the main suffered φ angle of normal structure module is 45-225 and the main suffered φ angle of advanced structure module is 60-240. Therefore, the advanced structure module not only decreases the light leakage at dark state but lets the suffered range not to be observed easily.

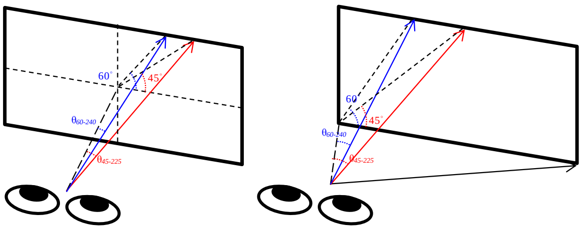


Figure (7) Observation angle at different φ angle

4. Conclusion

We demonstrate a 17.3" Mini-LEDs notebook module that could reach HDR1000 specification. In our result, we are success to improve the light leakage at dark area at large viewing angle and let the light leakage not easy to be observed. In the future, we would organize a human factor test to link the viewing angle data between human. Further, the information could work out a specification for NB or other application.

5. REFERENCE

[1] VESA DisplayHDR specification (https://displayhdr.org/performance-criteria/)

[2] I-Hsun Hsieh, Chien-Hung Kuo, Yi-Wen Chang, Hao-Hao Wu, Kuen-Yao Lee, Han-Ping Kuo, Yu-Hsiu Chang, Tzu-Ling Niu, Chiaen Fuh, Chao-Min Yang, Mao-Teng Ho, Yin-Ting Lee and Ya-Wen Chen. "The Process and Reliability of Mini-LED Displays", IDW, FMCp2-3. (2019)