Retinal Resolution Display Technology Brings Impact to VR Industry

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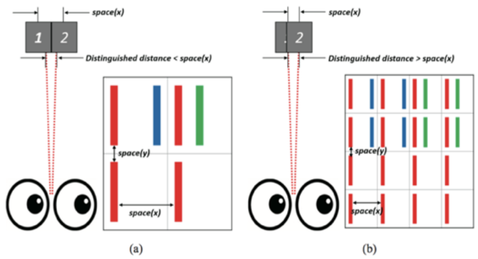

Fig. 1: *Schematic (a) human eye can see the dark region while two adjacent pixels having space higher than distinguished distance; (b) dark region is invisible at space is equivalent or lower than distinguished distance.*

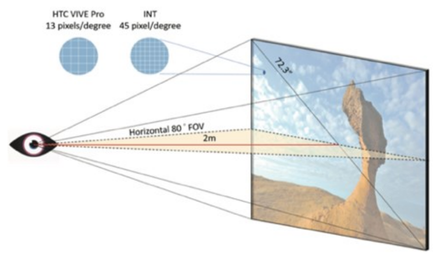

Fig. 2: *Schematic diagram contains the virtual image structure and difference of pixel per degree.*

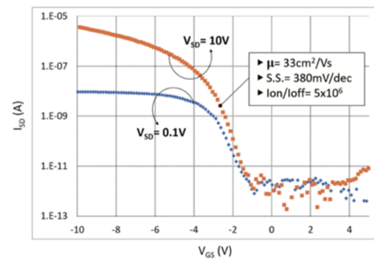

Fig. 3: *Id-Vg characteristics of TFT in UHPD's backplane.*

ABSTRACT

Currently [1], Visual Reality Head-mounted Display has several problems that need to be overcome, such as insufficient resolution of the display, latency, Vergence-accommodation Conflict, etc., while the resolution is not high enough, causing the virtual image of the display to have graininess or Screen-door Effect. These problems have brought VR users an imperfect image quality experience and are unable to achieve a good sense of immersion. Therefore, it is necessary to solve the problem of insufficient display resolution. INT TECH Co., is working towards this goal and has made very good progress.

CCS CONCEPTS

Hardware → Emerging technologies → Analysis and design of emerging devices and systems → Emerging architectures

ADDITIONAL KEYWORDS AND PHRASES

Virtual Reality, Display, AMOLED, High Resolution

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1 INTRODUCTION

Recent near-eye display has been most widely discussed and applied to games, entertainment, and the IoT (Internet of Things). Among them, the display is one of the key components, and the quality of the display determines how the user obtains a good virtual experience, especially in terms of color performance, display latency, FOV (Field of View) and ppd (Pixels per Degree). AMOLED (Active-Matrix Organic Light-Emitting Diode) is currently being used and the best technology that can meet the needs of near-eye display applications such as wide color space usage [Rajeswaran, et al. 2012], fast response time [Dawson, et al. 1998] and harmless blue light emission [Oh, et al. 2015]. However, simultaneous execution of large fields of view and good image quality cannot be considered at the same time. To obtain better image quality, OLEDoS (OLED on Silicon) has been developed and fabricated on a silicon wafer [Huang, et al. 2009], which proves its superior performance by increasing the pixel density or ppi (Pixel per Inch), but this technology is difficult to manufacture a size larger than 1" panel, which is limited by the size and area of the silicon wafer, requires higher manufacturing costs compared to the manufacturing process on the glass. Therefore, OLEDoS brings the limitation of low FOV, which prevents users from realizing an immersive environment

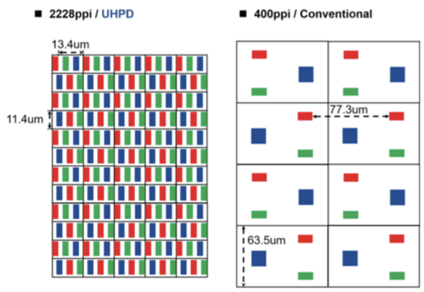

Fig. 4: *2228ppi/UHPD formed aperture ratio larger than 400ppi/conventional.*

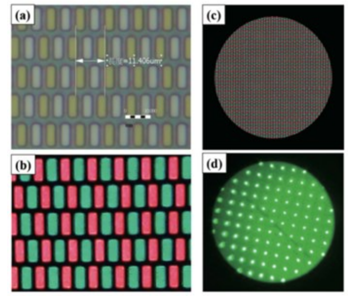

Fig. 5: *2228ppi/UHPD images captured under a microscope. (a) Un-driven before lighting on; (b) after lighting on; (c) and (d) 2228ppi and 400ppi appearance comparison at the same scope magnification.*

[Duh, et al. 2001]. In addition, when the user views the panel with a low pixel density at a short distance (3 to 4 cm), a SDE occurs on the virtual image, causing a serious defect in the image quality or ppd of the user (HTC VIVE PRO provides only 615ppi and 13ppd: 1440 horizontal pixels over a 110° monocular FOV). The UHPD (Ultra High Pixel Density) technology proposed by INT can simultaneously achieve an immersive large field of view (compare to OLEDoS based near-eye display) and impressive image quality, and an extremely high ppd can also effectively eliminate SDE.

2 IMPLEMENTATION AND RESULTS

Literally, UHPD means that many pixels are constructed in a narrow area, so the increase in pixel density makes the distance between adjacent pixels smaller. As shown in Fig. 1, the closer distance between pixels, it is more difficult to distinguish each pixel. The minimum distance that the virtual image can be recognized by the human eye is 11.4um, and the pixel density and ppd can be improved to 2228ppi and 45ppd (calculated with 80° monocular FOV and 2m virtual image distance, as shown in Fig. 2.) by narrowing the gap. To achieve extreme results, there are many technical obstacles that need to be overcome and can be divided into two areas: backplane TFT (Thin-Film Transistor) array and front-panel OLED display. The backplane provides sufficient drive capability (> 30 cm/Vs mobility, a subthreshold swing of <400 mV/dec and an I_{on} to I_{off} ratio of >10^6, As shown in Fig. 3) to allow the front-plane to be controlled and stabilized. The aperture ratio is one of the most important parameters for display manufacture. As pixel density increases, shirks and many other minor problems often occur, such as reduced brightness and operating lifetime, etc. The aperture ratio of RGB pixels is usually limited by conventional method. When the pixel density requirement is higher than 500ppi, the mechanical tension of the conventional method becomes more and more difficult to control, which makes it difficult to achieve high pixel density using the conventional method. Therefore, INT is trying to use the UHPD technology to optimize the OLED process to manufacture 2228ppi with pixel pitch 11.4um RGB pixels. RGB pixels can be freed from existing process limitations. The aperture ratio indicates how many areas are available for display, defined as follows,

$$A.R. = A_{color}/A_{unit}*100\% \quad (1)$$

where A_{color} is occupied area of the color block in specific color, A_{unit} is minimum repeatable area of collecting three colors. The proposed UHPD was evaluated by a simple straight-line SPR (Sub-Pixel Rendering). The UHPD process can optimize and achieve a large aperture ratio than the conventional method, as shown in Fig. 4. So far, it is generally believed that a larger ppi will result in a smaller aperture ratio. UHPD technology redefines the rules. Due to process limitations, the pixels have more non-luminous regions, the adjacent two red display pixels spacing is 77.3um, the aperture ratio is 5%. Compared with UHPD's 2228ppi, the adjacent two red display pixels spacing is only 13.4um, increasing the proportion of luminous area and non-luminous area, and obtained 17.3% aperture ratio. In Fig. 5(a) and Fig. 5(b) the dual colors are successfully driven and lighted. With the development of the UHPD technology, it is extremely high that high ppi is achievable. It can be observed from the figure that there is no problem of color mixing at such a high pixel density of 2228ppi. As shown in Fig. 5(c) and Fig. 5(d), it is easy to observe that when the pixel pitch is greatly changed, SDE gradually disappears.

3 CONCLUSIONS

A 2.17-inch AMOLED panels on glass substrates with extremely high pixel density, pixel per degree, and aperture ratio (2228ppi, 45ppd, and 17.3%) was demonstrated, INT achieved a breakthrough in the UHPD technology through integrated backplane TFT array and front-panel OLED display, providing a complete solution for near-eye display applications, effectively eliminating the screen door effect, and significantly enhancing the VR user experience.

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