Ultra high resolution imaging light measurement device for subpixel metrology of micro-LEDs and OLEDs

T.Steinel, J.Blanke, M.Wolf
Instrument Systems GmbH, Germany

1. Introduction

More pixels! This is a major trend in the display industry. More (i.e. smaller) pixels with higher fill factors are urgently needed for near-eye applications such as VR goggles (using, e.g., microdisplays or µ-LED displays). With the displays so close to the observer's eye, screen-door effects and pixel non-uniformities are easily visible and disturbing for the consumer. Micro-LEDs or Micro-OLED displays feature pixel sizes < 10 µm and equally small pixel pitches. For both technologies each single subpixel is a light source itself. Luminance and color variations between the pixels are thus likely and strongly influence the visual quality of the display. This means quality control and subsequent calibration of the displays is crucial. Tests on subpixel level under the constraints of a production environment (esp. tact times), become necessary and are challenging.

2. Ultra High Resolution ILMD

Here we present measurements of OLED displays performed with an innovative ultra-high resolution ILMD ("LumiTop X150") especially designed for display subpixel metrology in production lines. The innovative concept of the device merges a 150 megapixel RGB CMOS camera with the high-end spectroradiometer CAS 140D[1]. This concept guarantees spectroradiometric test accuracy across the whole image of the camera [2]. The very high resolution of 150 megapixels thereby allows subpixel level analysis of complete displays in one single shot. Therefore, this device provides very fast and very accurate quality control and pixel calibration of OLEDs or Micro-LED displays in production lines and in-depth analysis in the laboratory. An integrated pixel shift mechanism allows to even increase the resolution to effectively 600 megapixels.

3. Experimental Results

3.1 Micro-OLED Display

A 1" Micro-OLED display with an RGBW pixel scheme by Fraunhofer FEP [3] was investigated. The display resolution is 1920x1200 pixels at 2300ppi, which translates into a 5.5µm sub-pixel pitch. Figure 1 shows zoomed pictures of full display image measurements using an internal 4x4 pixel shifter. All sub-pixels are switched on in a white image (left). Green sub-pixels are displayed at a different zoom level (right). Sub-pixels are fully resolved in both cases and allow for further quantitative analysis.

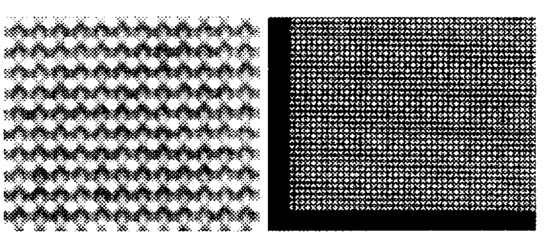

Figure 1: Micro-OLED display (RGBW) with 5.5µm sub-pixel pitch. Left: WHITE, right: GREEN

3.2 Defect Pixel Detection on OLED Display

Images of the full display of a 570ppi phone were taken with each pixel being fully resolved. Specific algorithms allow to derive pixel intensity (also: L, x, y etc.) maps for each display pixel as shown in Figure 2 for a part of the display. Another algorithm detects defect pixels according to user-defined criteria.

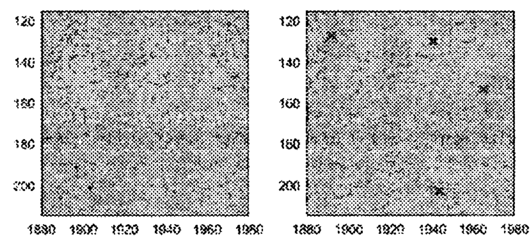

Figure 2: Intensity map and defect pixel detection

3.3 Conclusion

The ultra-high resolution data obtained by our device allows for the fast evaluation of luminance and color uniformity on a subpixel level. Using appropriate algorithms, luminance and color maps of the display are obtained to determine defect pixels and/or to calibrate OLED and µ-LED displays in-line.

4. Acknowledgements

We gratefully acknowledge the provision of the micro-display by Fraunhofer FEP.

5. References

[1] https://www.instrumentsystems.com//fileadmin/editors/downloads/Products/LumiTop2700_4000_e.pdf

[2] Spectrometer-Enhanced Imaging Colorimetry M. E. Becker, J. Neumeier, and M. Wolf, SID Symposium Digest of Technical Papers, **48** (2017)

[3] P. Wartenberg, M. Buljan, B. Richter, G. Haas, S. Brenner, M. Thieme, U. Vogel, P. Benitez, "High Frame-Rate 1" WUXGA OLED Microdisplay and Advanced Free-Form Optics for Ultra-Compact VR Headsets" SID symposium Digest of Technical Papers, Vol.**49**, pp. 514-517, 2018.