Modelling Electrical and Optical Cross-Talk between Adjacent Pixels in Organic Light-Emitting Diode Displays

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Electrical and optical coupling between adjacent pixels are arising limitations of the device performance in high PPI OLED displays. This cross-talk effect reduces the contrast ratio and can be detrimental for the color gamut of the device. We achieved a quantitative understanding of both electrical and optical cross-talk in OLED displays with our simulation software LAOSS. Regarding electrical cross-talk, up to 40% relative luminance between the addressed pixel and the neighbors due to parasitic currents through the common layers is found for a typical AMOLED device. For a WOLED/CF display, simulation of optical cross-talk reveals significant leakage of light to the neighboring pixels, which modifies the emitted color of the display in the far-field.

Introduction

As the distance between neighboring pixels in Organic Light-Emitting Diode (OLED) displays is shrinking in the trend towards higher pixel-per-inch (PPI) densities, electrical and optical coupling between adjacent pixels are arising limitations of the device performance. This effect, called cross-talk, reduces the contrast ratio and can be detrimental for the color gamut of the device. Cross-talk mitigation is a complex engineering problem that requires the combined optimization of several geometrical parameters. In a direct emission display the adjacent pixels can be electrically coupled through the lateral current of a common layer. Such leakage current results in unwanted light emission from an unaddressed pixel of different color. In devices combining white OLEDs (WOLEDs) and color filters (CF), the color gamut is additionally hampered by the leakage of light through a filter when the WOLED of an adjacent unit is addressed. In our contribution, we demonstrate how to achieve a quantitative understanding of both electrical and optical cross-talk in OLED displays by using the large-area multi-scale device simulation software LAOSS [1].

1) Modelling of electrical cross-talk in AMOLED devices

First, we describe the simulation and results obtained for an AMOLED test structure with roughly 300 PPI [2,3]. It is common practice for AMOLEDs to have non-patterned transport layers, which in our study are the hole injection/transport layers, together with the metallic top cathode. When the blue pixel is addressed, a residual parasitic current is flowing from the pixel patterned anode to the cathode of the adjacent pixel(s) through the common layers (Fig. 1). We found that the relative luminance between the addressed pixel and the neighbors can be as high as 40%, as shown in Fig. 2. This hampers significantly the quality of the final image. Our results are in agreement with different experimental observations that were reported previously [4].

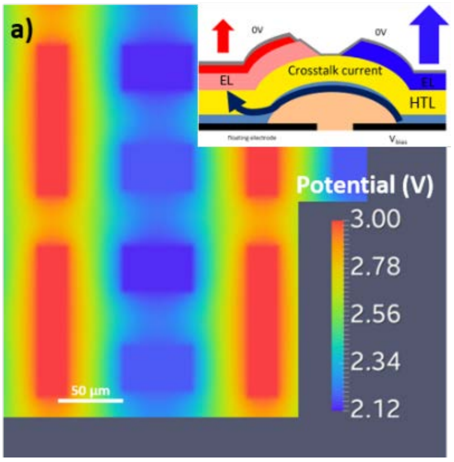

Figure 1: Simulated potential distribution in the common layers of the RGB OLED array under test. Only the blue pixels (elongated rectangles) are biased. The inset is a schematic of the array.

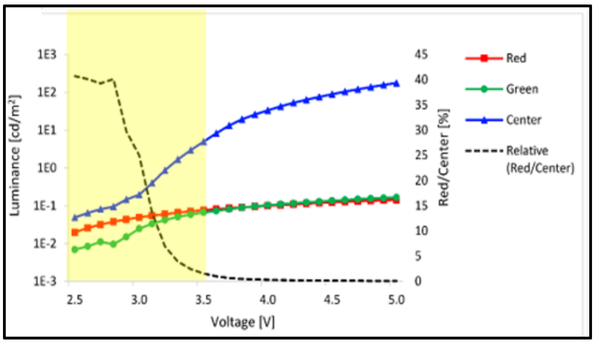

Figure 2: The ratio of parasitic to intended luminance (dashed line) is as high as 40% in the low voltage regime.

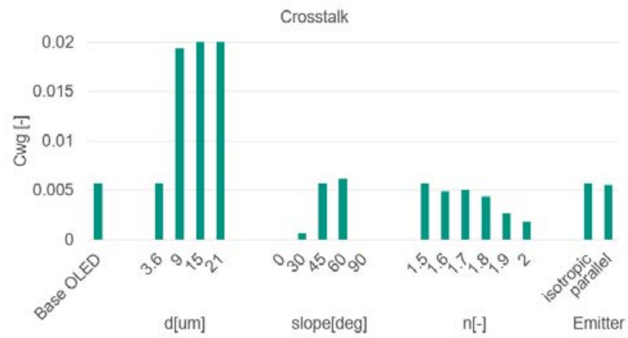

Figure 4: (Optical) cross-talk index (Cwg=white EL/green EL) of the white pixel for different Pixel configurations and OLED parameters.

2) Simulation of optical cross-talk in WOLED/CF displays

In the second part, we present our simulation of optical cross-talking in a WOLED/CF display [5]. The test structure in LAOSS is represented by two interfaces, one at the OLED plane and the other at the CF plane, separated by a known distance [Fig. 3 (a)]. It is demonstrated that a significant amount of light is not emitted through the filter above the addressed pixel but is leaking to the neighboring white and blue pixels, especially at wavelengths in the blue region of the spectrum [Fig. 3 (b)]. This non-negligible contribution of light leakage modifies the emitted color of the display in the far-field.

Optical cross-talk is evaluated in terms of the cross-talk indices for the different pixels shown in Fig. 3(a), which correspond to the relative emission intensity with respect to the emission of the green pixel. Design parameters that are varied to assess their impact on the optical cross-talk include the thickness of the encapsulation layer, the slope of the pixel walls, the refractive index of the encapsulation, as well as the emitter orientation of the OLED. Figure 4 shows the dependence of the cross-talk index of the white pixel on variations of these parameters. It is found that cross-talk is minimized for thin encapsulation layers and nearly vertical pixel walls, and that the emitter orientation is not relevant.

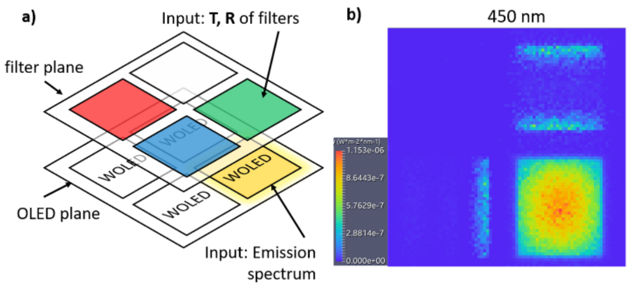

Figure 3 a) Schematic of the WOLED/CF array used in the simulation. b) Distribution of the outcoming light when only the green unit (low right corner) is addressed.

Finally, electrical and optical cross-talk are assessed in a combined optical-electrical simulation of the pixel array. This reveals the detrimental impact of reduced inter-pixel distance in high-density displays (Fig. 5).

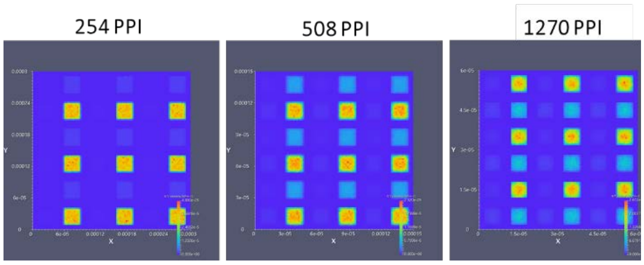

Figure 5: Combined simulation of electrical and optical cross-talk for pixel arrays with increasing pixel density, exhibiting severely enhanced cross-talk.

Conclusion

We demonstrate a comprehensive multi-scale simulation approach to electrical and optical cross-talk in high-density AMOLED and WOLED/CF displays. Owing to the consideration of the key material and geometry parameters of OLED and pixel structures, both qualitative understanding of the origins and quantitative assessment of the undesired phenomena is enabled, which paves the way for effective cross-talk mitigation in future device designs.

References

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