Feasibility Study of Traditional Demura Technology Applied to MicroLEDs

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ABSTRACT

Demura, a technology that adjusts pixel brightness to improve the mura effect of a display, has been widely employed in AMOLEDs. We perform Demura verification on a 7.56-inch 240x320 resolution MicroLED with PAM driving mode in this study, and we examine the compensation distortion issue that exists during the process.

1 Introduction

Demura technology is widely employed in many AMOLED product forms as a way for properly repairing the display's mura [1-2]. This technology does not depend on product process development and can achieve a uniform and smooth display effect solely through accurate display data operation, opening the way for AMOLEDs to eventually replace TFT-LCDs.

MicroLED has recently received a lot of attention as the next-generation display technology following AMOLED [3-4]. MicroLED, like AMOLED, has to deal with the problem of mura, according to the results of numerous samples. The current MicroLED technology, on the other hand, is still being demonstrated and optimized, and there is still space for process improvement to increase mura. When a process isn't experiencing a bottleneck and can't go any further, demura is employed as the final approach to enhance mura.

Although both MicroLEDs and AMOLEDs are electroluminescent devices, their materials, designs, and manufacturing processes are vastly different. PAM mode is a more established AMOLED driving mode [5], but MicroLED is frequently used to refer to the PWM mode [6]. This is mostly owing to the fact that the efficiency and luminescence properties of MicroLED devices vary greatly depending on the current density, and PWM mode efficiently resolves these difficulties [7]. PWM mode, on the other hand, has a number of issues to resolve, including gamma curve debugging and driver chip customization difficulties.

We attempt Demura verification for a MicroLED sample using PAM driving mode in this paper. We employ the AMOLED Demura function fitting method in the verification process, and we study the causes of Demura compensation distortion from the perspective of MicroLED's unique characteristics, as well as providing algorithmic improvement solutions.

2 Experiment

The Demura verification target was a 7.56-inch 240x320 resolution MicroLED. The sample is employs a mass transfer technology with 80x80 pixel arrays per transfer and made up of 3x4 shots. The sample only finished the transfer of 10 shots because to the immaturity of the procedure, and there were a number of faulty dots sporadically scattered throughout the effective display area. However, the sample was able to determine the form of the mura and the luminance difference between the Shots, which can be used as a basis for analyzing the Demura compensating effect.

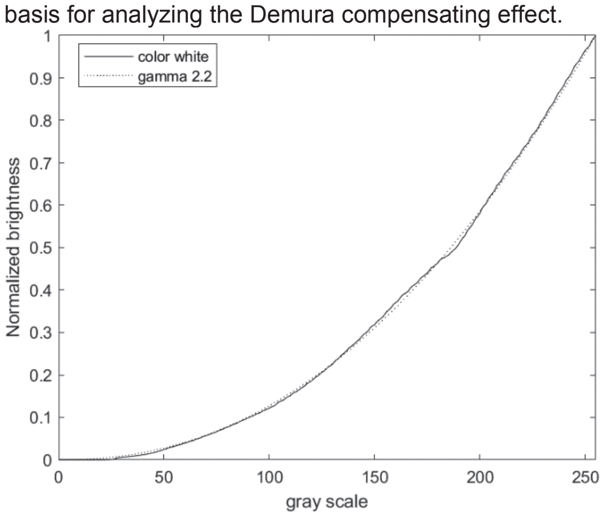

Fig. 1 The relationship between white brightness and gray scale

Using a color analyzer model Konica Minolta CA-310, the MicroLED sample was optically corrected for white gray scale luminance and color coordinates according to Gamma 2.2 and CIE(0.25,0.30) standards (Fig. 1). The 32, 64, 96, 128, 160, 192, and 244 gray scales for the sample R, G, and B pure colors were taken using a CCD model Radiant ProMetric Y29. The relative luminance data is gathered after capturing images, and the same reference system is utilized for different gray levels of each color, therefore the different reference systems between different colors cannot be directly compared.

3 Results

The Demura compensation target area is the screen area covered by the color analyzer probe when doing Gamma and CIE optical correction. The calibration target value for all sub-pixels of the whole sample is taken as the average value of all sub-pixels of this area with varied gray scale rawdata corresponding to different colors of R, G, and B.

It is important to establish the correct functional relationship based on rawdata calculation in order to determine the offset value of each subpixel that needs to be compensated at different gray levels. Draw the scatter distribution of rawdata and gray scale for each sub-pixel or set of sub-pixels with the same luminous properties, and use tools like Matlab to fit the scatter distribution as a function of rawdata-gray, fitting the reference function as follows:

$$f(x) = A \times x^B + C$$

The constants obtained after fitting the function to each sub-pixel or set of sub-pixels are A, B, and C.

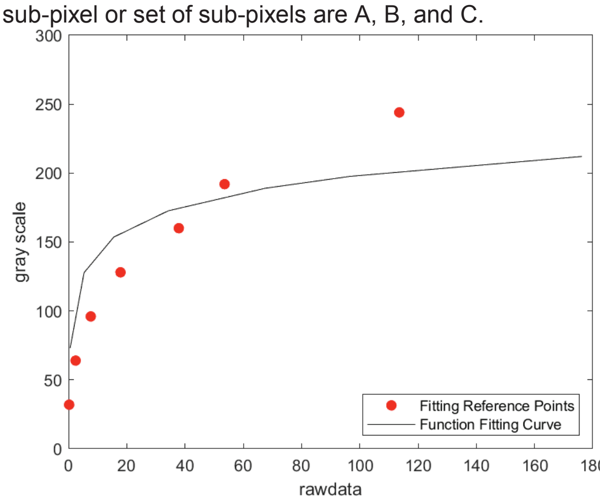

Fig. 2 Function fitting failure cases

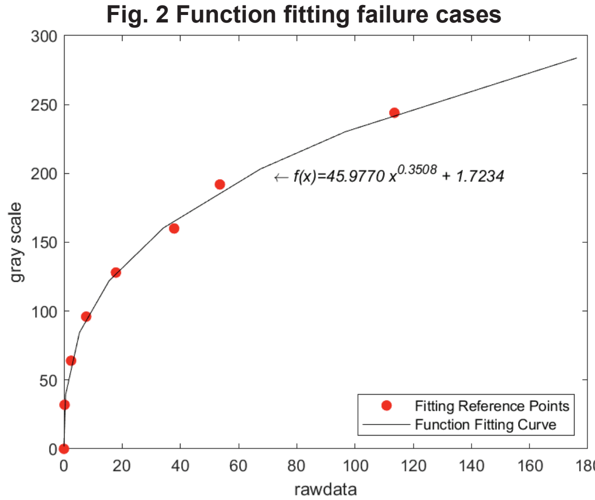

Fig. 3 The function is fitted successfully

Based on the present rawdata, a fit failure prompt and an error result are returned during the function fitting procedure (Fig. 2). It demonstrates that the luminous characteristics of MicroLEDs in regard to gray scale are not adequately described by the above reference function. The function failed owing to the deviation of the distribution of individual points, according to the scatter distribution of a specific set of rawdata-gray. The influence of individual point distribution deviation on function fitting can be avoided by re-optimizing the function fitting circumstances, such as adding auxiliary reference points or eliminating the distribution deviation points (Fig. 3).

The actual compensatory impact was detected when the offset values produced based on the above fitting were mixed with the data to be displayed. At one gray scale, the offset value was found to be excessively great, resulting in overcompensation and an uneven distribution of bright dots in the MicroLED after compensation (Fig. 4 and 5).

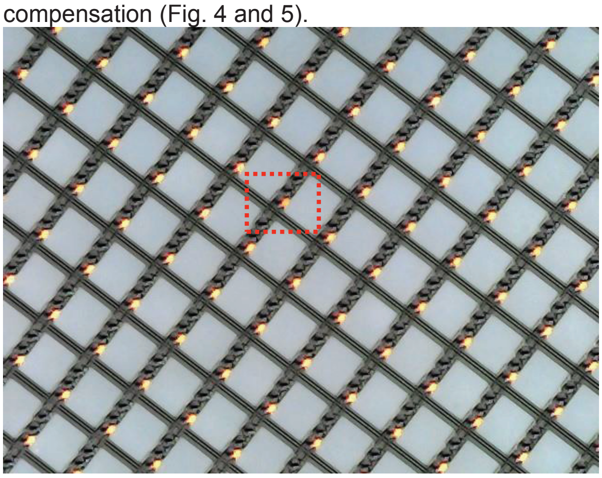

Fig. 4 Dark dot before compensation

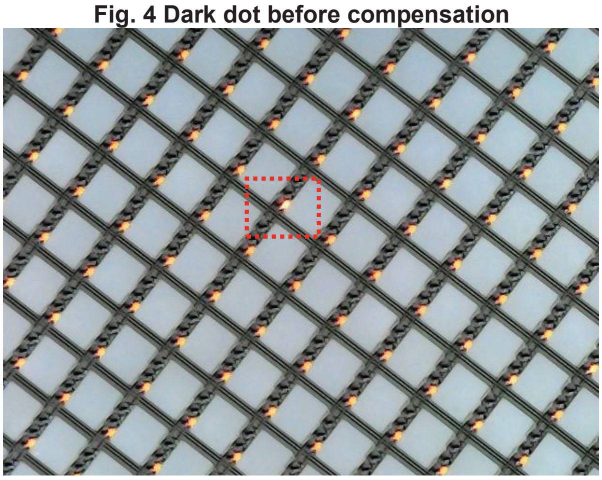

Fig. 5 Bright dot due to overcompensation

The foregoing studies show that when employing AMOLED's current proven Demura scheme to correct for MicroLEDs with PAM operating mode, compensation failure or anomalous bright dots distribution occurs, and this issue will be discussed in the next part.

4 Discussion

The function fitting of rawdata-gray scatter distribution for each sub-pixel or group of sub-pixels with consistent luminescence characteristics is a set of methods developed by Demura technology in the AMOLED field over time that can accurately describe the luminescence characteristics of AMOLED products and realize accurate compensation while using less computing resources, making it ideal for industrial scale production.

To achieve the aim of compensating mura, Demura technology calculates the difference between the actual display brightness of each sub-pixel and the expected display brightness, converts this difference into gray scale values, and finally merges these with the desired display gray scale data. The offset value can be calculated in a variety of methods, and function fitting is just one of them. To investigate the aforesaid overcompensation phenomena, this work reconstructs the Demura compensation algorithm using linear interpolation calculations. Although this approach has the advantage of precisely describing the rawdata-gray scatter distribution pattern, it is not widely employed due to the high cost of temporary processing and storage resources.

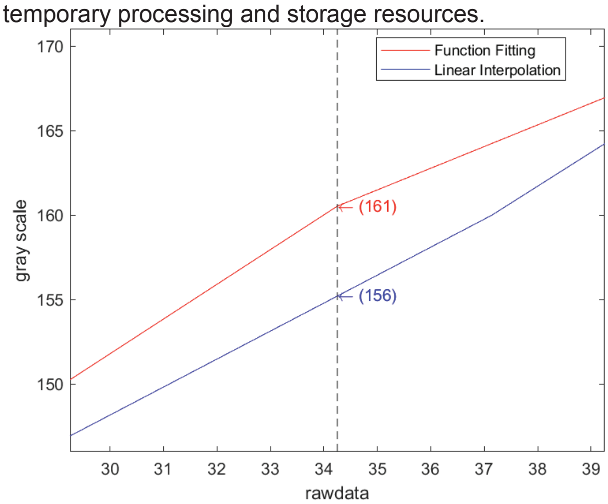

Fig. 6 Differences in local results between function fitting and linear interpolation

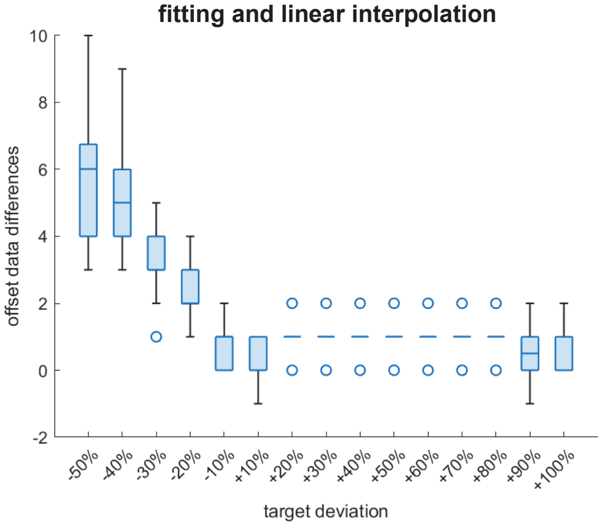

Fig. 7 Distribution of differences between function fitting and linear interpolation under different compensation deviations

The linear interpolation approach was used to re-apply Demura compensation to the above samples, and a considerable computational bias was discovered at the position of the individual rawdata-gray point distribution deviations (Fig. 6). The values generated by the function fitting method for the identical target luminance are nearly 10 gray levels bigger than those calculated by the linear interpolation algorithm in this distribution deviation zone (Fig. 7). This also explains why, after Demura adjustment with the function fitting technique, the MicroLED has an inconsistent distribution of brightness dots.

We tested the brightness and chromaticity relationship of R, G, and B monochromatic colors at different gray levels in order to better understand the individual points distribution deviation phenomenon of rawdata-gray scattering distribution (Fig. 8 and 9). The distribution deviation phenomena may also be seen in monochromatic color luminance-grayscale curves, albeit the magnitude of the deviation changes significantly depending on the luminance. At the same time, as the junction changes, the chromaticity of the monochromatic color changes as well, and the location of the abrupt shift correlates to the rawdata-gray distribution deviation.

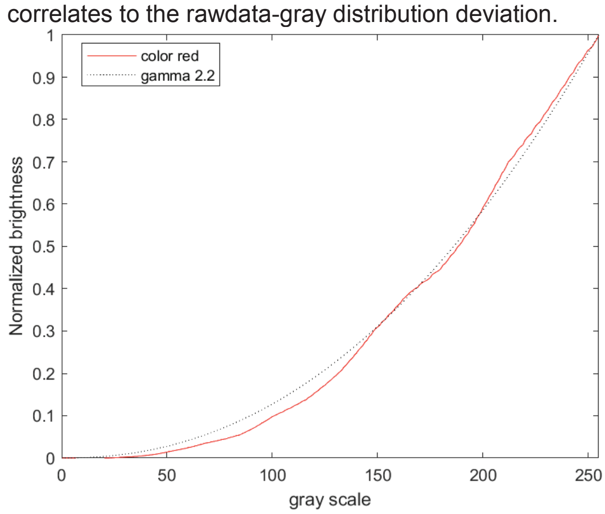

Fig. 8 The relationship between red brightness and gray scale

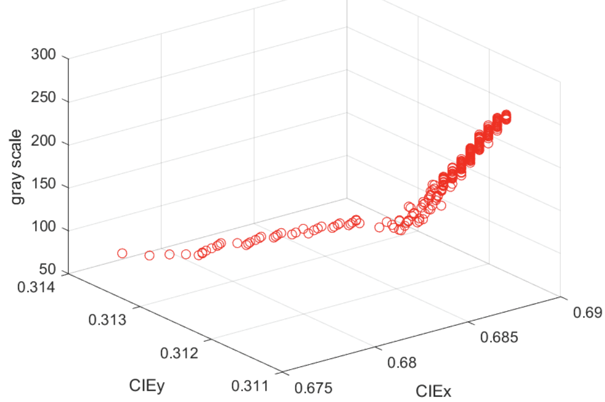

Fig. 9 The relationship between the red color coordinates and the gray scale

Each white gray scale must meet particular brightness and chromaticity standards when the sample is optically adjusted for Gamma and CIE. Because the white color is made up of a mixture of R, G, and B, if the color coordinates of a single color are changed during the gray scale correction process, the brightness ratio of R, G, and B must be readjusted in order to attain the white color's goal color coordinates. This will produce changes in the relationship curve between monochromatic luminance and gray scale, which will lead to deviations in the rawdata-gray scattering distribution.

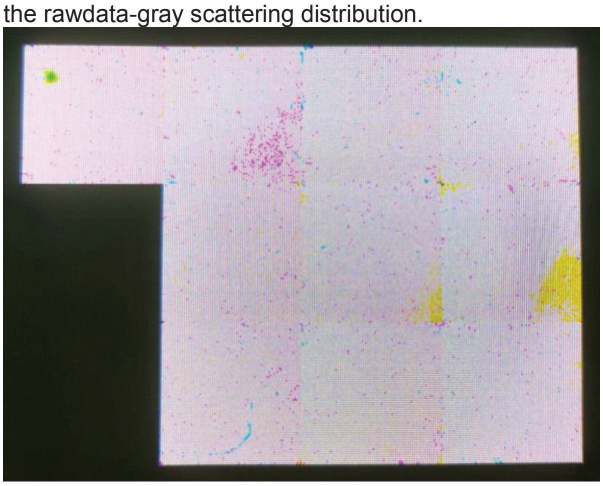

Fig. 10 128 grayscale before Demura

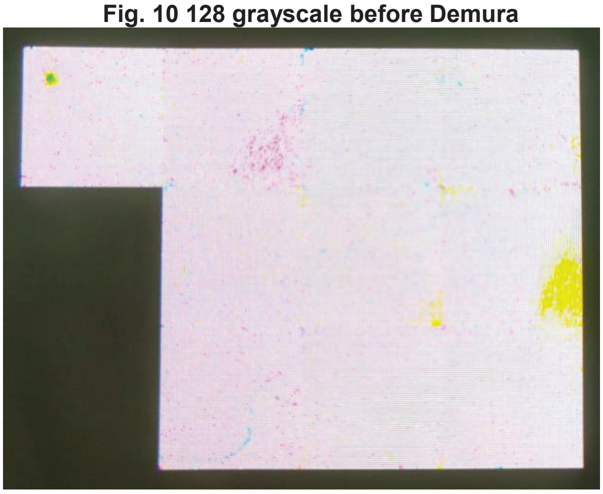

Fig. 11 128 grayscale after Demura

At varied current densities, MicroLEDs have their own properties of changing luminous efficiency and color coordinates. This is why PWM driving mode for MicroLEDs is frequently discussed; it can disguise this issue so that individuals are not easily detected. However, the PAM driving mode unquestionably reveals all of the issues with MicroLEDs, making it impossible to directly apply the proven Demura compensation system in the AMOLED sector.

5 Conclusions

In summary, MicroLEDs with PAM driving mode have the property that their monochromatic pixel color coordinates change with changes in current density, causing color matching to change during optical correction, resulting in an abnormal deviation of the monochromatic luminance versus gray scale curve. Demura's function fitting approach is hampered by this variance, which is immediately represented in the scatter distribution rawdata-gray.

The PAM driving mode is not a good choice for MicroLED because of its device features. This not only affects the optical display's performance, but also poses a significant challenge to the Demura technology's applicability.

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