P-185: A High Efficiency Compact Size Color-Sequential LCOS Projection Engine with 100% NTSC

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Abstract

*A CS-LCOS based projection system with high efficiency and compact size is developed. The light collection system is optimized to obtain about 75% coupling efficiency from LED to LCOS surface. More than 10% of the throughput of the overall system is expected with considering the collection efficiency, color mixing, polarization, surface reflection, and efficiency of each component. Measurement results show around 30 lumen flux output at 8 watts power input including LED and LCOS driving request, which is accordance with the design evaluation. The size of the demo is around 65mm*50mm*17mm, with a total volume of 55CC. Almost 100% NTSC is achieved with the benefit of sequential color generated with RGB LED shining and fast LC response.*

1. Introduction

Mobile devices are becoming an important part of our daily life. The emerging embedded, detachable or portable standalone projection optical modules [1-2] may greatly broaden the applications in not only entertainments but also business. With the improvement in high resolution spatial light modulators, LEDs with higher efficiency, and compact optics, this ongoing trend will provide a potential unique selling point for handheld electronic devices.

Digital light processing (DLP) and Liquid-crystal-on-silicon (LCOS), including Color-Sequential (CS) type [3-4] and Color-Filter (CF) type LCOS [5], are the three most promising technologies for compact size projection display application. Table 1 gives a comparison among these different imager technologies, in the ways of color performance, resolution, system efficiency, system size and cost.

CF-LCOS based system has the advantages of low cost and compact configuration [1, 6-7], which is regarded as the most promising for embedded mobile phone projector application. While with a stronger demand for higher image quality, such as image color and resolution, CS-LCOS based projection system will provide more satisfied solutions with balanced considerations in both quality and cost.

In this paper, an optical engine based on red, green, and blue (RGB) LED sources and CS-LCOS is proposed. The light collection system is optimized to obtain about 75% coupling efficiency from LED to LCOS surface. More than 10% of the throughput of the overall system is expected with considering the collection efficiency, polarization, surface reflection, and efficiency of each component. The total volume of the design is about 55 Cubic Centimeter (CC), which is suitable for portable standalone application. It can produce a 15inch image at 0.6 meter distance. Almost 100% NTSC is achieved with the benefit of sequential color generated with RGB LED shining and fast liquid crystal response.

Table 1: Imager technologies comparison

	DLP	CS-LCOS	CF-LCOS
Color performance	++	++	-
Resolution	-	++	+
Power efficiency	++	+	+
Optical engine system size	+	+	++
Cost	-	+	++

2. CS type LCOS projector configuration and optimization

Figure 1(a) illustrates the schematic diagram of a CS-LCOS projection engine system. Basically, it consists of illumination optics, color mixing module, lighting integrator or beam shaper, polarization beam splitter (PBS), imager and projection lens. Color mixing could be achieved through different ways, such as optical components like dichroic mirror and x-cube, or RGB LEDs in one chip with integrating rod. Light integrators could be placed before or after the color mixing module [8], depending on design architecture. Lens array placed after color mixing module with proper curvature and illumination design, has better

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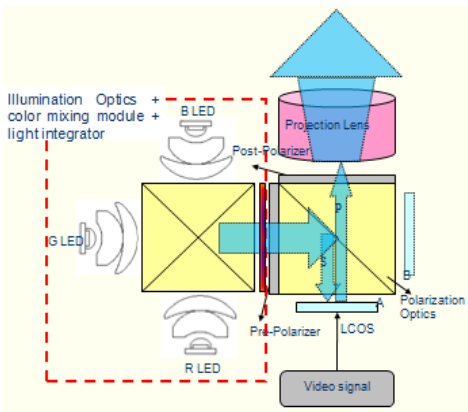
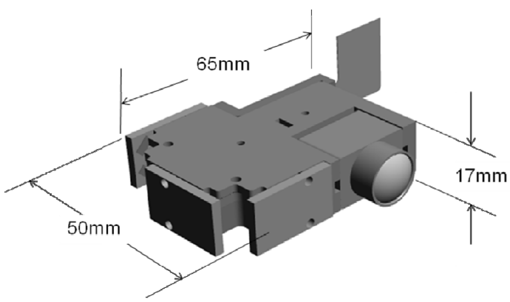
chance to achieve a smaller size projection system and better color uniformity. Whether the imager be placed at position A or B depends on properties of PBS. Figure 1(b) shows our design with outmost mechanical dimension, which applies the configuration with lens array and x-cube.



(a)



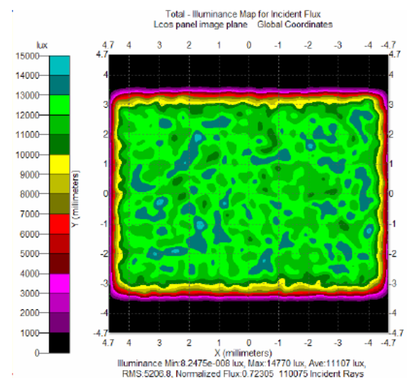
(b)

Figure 1. (a) Schematic diagram of CS-LCOS projection system (b) View of optical engine

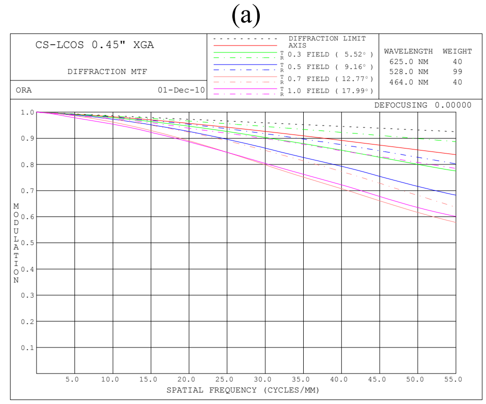
Illumination optics plays an important role in achieving a projection system with small size and high efficiency. Before performing the optimization, it is critical to select suitable LEDs, according to the imager size and design target, with the guidance of etendue calculation. In our design, we choose a 0.45 inch diagonal CS-LCOS from Himaxdisplay [9], with resolution of 1024*768. For the consideration of coupling efficiency, it is suggested that the etendue of light emitted from LED to be less than the etendue of light utilized by imager. Assuming the system F/# to F/1.8, we found that the PT39 from Luminus, and Q9WP from OSRAM are the 2 most suitable choices. Considering the system size and cost, we choose Q9WP in our design. Table 2 makes an evaluation of the system throughput. It shows that about 10% of the system efficiency is expected. 30lm flux would be achieved with 300lm input, which is about 7W power consumption of RGB LED. Figure 2 shows the optimization results of illumination optics and projection lens respectively.

Table 2: Evaluation of system efficiency

Throughput	Transmission	Lumens
LED Lumen Output	100%	300.00
Collection Efficiency	75%	225.00
Surface reflection	92%	207.00
Light combination	85%	175.95
Duty cycle	80%	140.76
Pre-polarization + recycling	50%	70.38
PBS-Rs	99%	69.68
LCOS	65%	45.29
PBS-Tp	75%	33.97
Projection Lens	90%	30.57
Total	10.190%	30.57



(a)



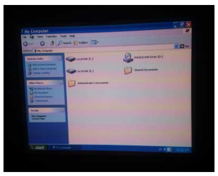
(b)

Figure 2: (a) Light Patch on LCOS panel (b) MTF of the projection lens

3. Results

We make 2 pieces of mock-up samples according the optimized optical design. The projected image is as shown in Figure 3. The brightness and color performance is measured by Konica Minolta chroma meter CL200A. The measurement is done in a dark room with environmental illuminance less than 0.1lx. The distance between the optical engine sample to the screen is 160cm, with projected image of the size 80cm*60cm. The measured 9points illuminance at both bright and dark state is shown in Table 3(a). The measured color coordinate is listed in

Table 3(b). By summarizing the measurement data, it shows that about 28 peak lm, more than 80% uniformity, CR of 169, and 95% NTSC is obtained. Since it is mock-up samples, the anti-reflection coating on the optical surface is not good enough and could be further improved, to achieve higher flux output. The results are accordance with evaluation.



(a)

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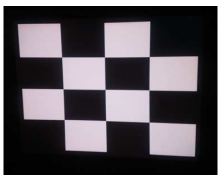
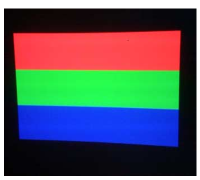


(c)

(d)



(e)

Figure 3: Projected image of mock-up sample. (a). desktop (b). bright state (c). checkerboard (d). grayscales (e). RGB color

Table 3: (a). Measured 9 points illuminance of bright state and dark state respectively

(b). Measured color performance

Dark State			Bright State		
0.2	0.2	0.3	48.6	52.8	43.4
0.3	0.3	0.3	52.6	58.4	49.1
0.3	0.4	0.4	50.6	54.5	46.4
Average: 0.30lx			Average: 50.71lx		

(a)

	x	y
R	0.6338	0.3115
G	0.1830	0.6840
B	0.1502	0.0480
W	0.2994	0.3220

(b)

Table 4: Summary of measured data

CR	169.04
ANSI lm	24.34
PEAK lm	28.03
Uniformity	80.91%
NTSC	94.48%
Color Temperature(K)	7350

4. Conclusion

We have reported a high efficiency projection system with compact size. The size of the demo is around 65mm*50mm*17mm, with a total volume of 55CC, which is suitable for portable applications. The light collection system is optimized to obtain about 75% coupling efficiency from LED to LCOS surface. More than 10% of the throughput of the overall system is expected with considering the collection efficiency, polarization, surface reflection, and efficiency of each component. It could deliver 30 lumens brightness at 8W of power input for LED and LCOS driving request. With the benefit of RGB LED lighting and fast LC response, almost 100% NTSC could be achieved.

5. References

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