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The Hybrid Light Source for Projection Display

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Abstract

A scheme of hybrid light source using lasers and LEDs for projection display is presented; the simulation results show that projectors with the proposed scheme can achieve high brightness of over 1000 lm, good uniformity of illumination and chromaticity. It also provides an improved method for light source with longer life, wider color garment and higher adaptability to environment which can replace UHP in traditional projectors.

Keywords

Light Source in UHP, Laser, LED

1. Introduction

Lasers and LEDs, as two types of new light sources, have been used in projection area for years [1]-[3]. Lasers are generally used in the area of micro-projection and large movie theatres projection, for its high brightness, good directivity, long life time, environmentally friendly and energy saving characteristics [4] [5]. Despite the above advantages, it is still far more expensive than conventional light sources, which prevents a wide range of its applications. LEDs are more widely used than lasers in projectors for its low cost as we all know [6] [7]. But its low brightness, especially for green LEDs, prevents it being used in mainstream commercial projectors. In order to overcome the above shortcomings, a new kind of light source composed of lasers, LEDs and phosphor powder, has been proposed and commercialized [8]. In this method, green colors are generated by ways that blue lasers stimulate the phosphor. In this paper, we propose a novel hybrid light source scheme, in which green lights are composed of green lasers and green LEDs, in the way that the brightness of green color is substantially increased by green lasers. The simulation results show that projectors with the proposed scheme can achieve high brightness of over 1000 lm, good uniformity of illumination and chromaticity.

2. Comparison between the Light Sources

The main parameters of hybrid light source (composed of lasers, LEDs and phosphor powder), pure Lasers and pure LEDs are listed in **Table 1**, which depicts their differences.

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Table 1. Comparison between the new light sources

Type	Color	Efficiency	Flux from the projector	Color garment	Life
	R (Luminus)	~7% - 8%			
LEDs	G (Luminus)	~4%	10 - 500 lm	105%	~20,000 hr
	B (Luminus)	~8% - 10%			
	R (Mitsubishi)	~40%			
Lasers	G (PHOEV)	20%	10 - 20,000 lm	~200%	10,000 - 20,000 hr
	B (Nichia)	20%			
	R (Luminus)	~7% - 8%			
Hybrid	G (phosphor)	~14%	1000 - 3000 lm	~80%	10,000 - 20,000 hr
	B (Nichia)	20%			

3. Lens Design and Analysis

3.1. Principles of Etendue

In conventional LED projection design, it is of particular importance to pay attention to the Etendue of the LED and that it is properly matched to that of the system.

For rotationally-symmetric optical systems with half aperture angle α:

$$E = n^2 \cdot \pi \cdot \sin^2(\alpha) \cdot A \tag{1}$$

For 0.7" imager with acceptance angle of ±12˚ and aspect ratio of 4:3, E_{system} = 16.16 mm^2, for a fiber coupled laser, if the diameter of the fiber is 0.4 mm, NA = 0.22, then E_{laser} = 0.019 mm^2, for LEDs, if we choose PT54 as the light source, then E_{LED} = 16.96 mm^2.

We can see that E_{laser} can almost be ignored compared to E_{LED} , but we can achieve power of more than 6 W, almost more than 3600 lm than that from E_{laser}. Meanwhile, we are only able to achieve 1000 - 2000 lm from E_{LED}. So it is possible for us to obtain such light source which is more than 4600 - 5600 lm with Etendue below 17 mm^2, which is almost the same as E_{system}.

3.2. Optical Structure of the Hybrid Light Source

RGB light from LEDs is collimated by micro objective, then overlapped by an X-plate, focused into integration rod. Decoherenced green Lasers are imported from the pinhole in the reflector plate, as depicted in **Figure 1**. Both Lasers and LEDs have the same optical axis. Unlike conventional design, field lens are added at the focal plane , which is near the entrance of the integration rod, as depicted in **Figure 2**. Because the field lens are at the position of the image place of LEDs, so they have a very small impact on the features of the image such as size, angle and Etendue.

As regard to lasers, field lens are not at the position of their focus place. Decoherenced green lasers are collimated by focusing lens and focused by field lens to a specified cone angle, which is helpful for good uniformity of illumination and chromaticity. Although lasers and LEDs do not have the same focal plane, Lasers have much narrower beam width which makes it easy to get into the integration rod without loss.

3.3. Green Lasers

Green lasers from fibers are decoherenced by a diffuser, the decoherenced lasers are imaged into the position where a pinhole is placed, as depicted in **Figure 3**. Careful design of the diameter and the location of the pinhole in the optical system are needed, to meet the following requirements:

1) The degree of the decoherence of the green lasers.

The more decoherence of the green lasers, the more increased the amount of Etendue of the green lasers, which will enlarge the diameter of the pinhole to prevent the lasers from blocking, while at the same time more light from green LEDs will escape from the pinhole. So we should make the balance.

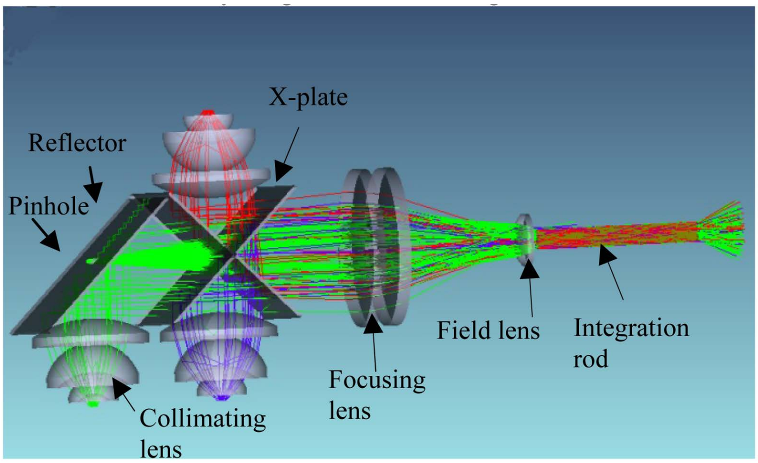

Figure 1. Optical structure of the hybrid light source.

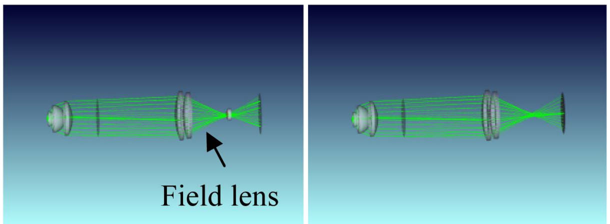

Figure 2. New design and conventional design.

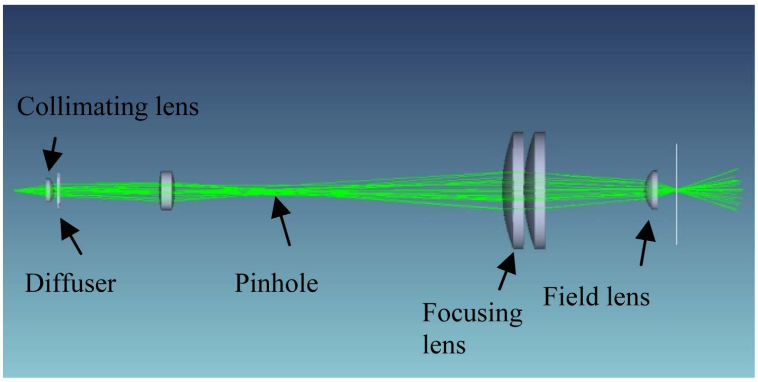

Figure 3. Optical path of decoherenced green lasers

2) The specified cone angle for illumination and coaxial features of LEDs and Lasers.

The high power, small size and commercialized green lasers provided by Phoebus vision are demonstrated in **Figure 4**. More than 6W green lasers are outputted from a very compact volume, which can be integrated into hybrid light source with LEDs, through the method mentioned above, to help projectors with over 1000 lm output.

4. Simulation

In the simulation, we put six detectors at the exit of the integration rod, each detector can obtain illumination information and color coordinates. The simulation results show that a good color uniformity of Δx'y' < 0.01 and a good illumination uniformity of >90% can be achieved (**Figure 5**).

We find in the simulation that the coaxial performance between lasers and LEDs is of particular importance to the uniformity of illumination and chromaticity.

Figure 4. Green lasers

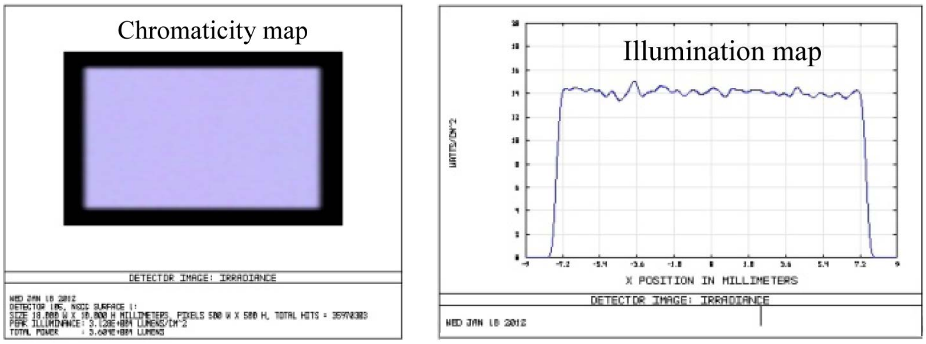

Figure 5. The simulation of illumination and chromaticity map.

5. Conclusion

A scheme of hybrid light source composed of lasers and LEDs for projection display is presented; the simulation results show that projectors with high brightness of more than 1000 lm, good uniformity of illumination and chromaticity can be achieved. It can be used as a new kind of projection light source with high cost-performance.

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