Development of a High-Intensity Projector Using LED Light Source

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Abstract

As a result of pursuing eco-awareness, long service life, freedom from maintenance and high color reproduction of projectors, more and more projectors are adopting solid-state light source devices. Under this trend, NEC Display Solutions is developing a 3-panel LCD projector that uses LEDs as the light source. The much larger color gamut of the LED light source compared to the conventional light source allows this product to achieve an Adobe ® RGB coverage of 98%, a level that has been hitherto impossible with traditional projectors. At the same time a long service life, freedom from maintenance and high color reproduction characteristics are also implemented.

Keywords

projector, LED light source, LED control, color reproduction, cooling technology

1. Introduction

In recent years, general lighting equipment, LCD panels and TVs are rapidly adopting the LED light source in order to extend product life time and to reduce power consumption. In the case of projectors that use mainly high-pressure mercury lamps as light sources, those using LEDs as the light source (hereinafter referred to as LED projectors) are being developed with the aim of improving service life, superior color purity and a more effective lighting performance. In this paper we use the prototype of our newly developed projector (development name: Sirius) as an example (**Fig. 1**). With this device, we aim to introduce the technology for achieving a practical-level brightness of 2,000 lumens, a high color reproduction of an Adobe ® RGB [*1] coverage of 98% and a long life of 30,000 hours.

Fig. 1 External view of the Sirius prototype.

2. High Intensity Light Technology

The light-emitting area of the lamps used in projectors is as small as below 1 mm ^{2} . The small area of the light-emitting section is a very important factor in increasing the light intensity efficiently. Small LEDs with a light-emitting area of about 2 mm ^{2} have high light-emitting efficiency but their light intensity is too low for use in the manufacture of general projectors with a brightness of 2,000 lumens or more. While general LED projectors use an LED for each of the red/green/blue primary colors, we have developed a unique high-efficiency lighting system for the Sirius by employing multiple LEDs of large size and high power. In addition, we have adopted LCD panel type optics to make full use of the multiple light fluxes obtained from the light source, and have developed a boost technology for using LEDs of various colors at maximum intensities.

With the LEDs currently under development, specific headroom is produced in the light intensities of red and blue when white is produced according to the light intensity of green. In order to render bright images in a wide color range, the Sirius employs unique optics capable of boosting the green light in-

[*1] Adobe ® RGB refers to the color space defined by Adobe Systems Incorporated. With much wider color reproduction regions than the sRGB standard, it is capable of more delicate color tone reproductions.

tensity so that the red and blue light intensities can be used at maximum without leaving headroom. In addition, since the light-emitting efficiency of LEDs is significantly affected by the device cooling conditions, we have adopted a liquid-cooling system optimized for projectors in order to efficiently cool the multiple LEDs. By incorporating Peltier devices, this system can control the high-power LEDs at a low temperature and obtain a high light-emitting efficiency stably.

Table shows the main system specifications of the Sirius.

3. LED Control Technology

The LED projector creates white light by synthesizing the RGB lights. Accurate white cannot be produced if the RGB light intensities are not balanced properly. Although the LED is a light source with a very long life, the light intensity drops gradually as the device is used, and the intensity deterioration rate is variable between RGBs. To deal with this, Sirius incorporates special circuitry that senses the LED intensities and adjusts the white balance automatically. The resulting maintenance of the optimum light intensity ratio makes it possible to keep the white color constant for a long period (**Fig. 2**).

Table Main system specifications of LED-PJ Sirius.

Item	Details
System	3LCD system
Pixels	1,024 × 768 (768,432 pixels)
Light source	LED
Brightness	2,000 lm
Light source life	30,000 hours
xy chromaticity regions	123% compared to Adobe® RGB (Coverage: 98%)
External dimensions	460 × 390 × 165 mm
Weight	13.5 kg

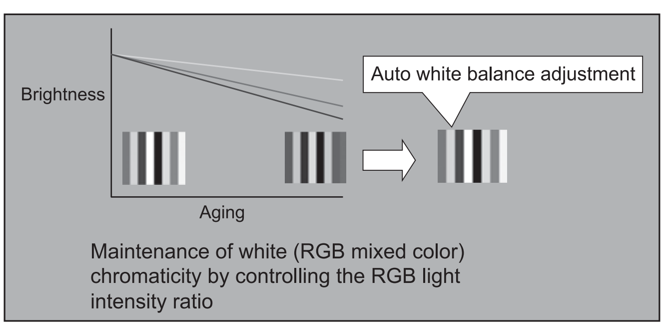

Fig. 2 Auto white balance adjustment.

The red LED is known to be the most easily prone to intensity and color variations due to temperature changes. We succeeded in keeping the red LEDs at a low temperature and to thereby obtain optimal performance from them.

4. Color Reproduction Technologies

The red, green and blue colors emitted from the LEDs are of high purity and provide a wider gamut than the xy chromaticity regions of the Adobe ® RGB standard. Nevertheless, the color coordinates of these colors do not always match the coordinates defined by the standard. In order to achieve accurate color reproduction, it is required to align the RGB coordinates with the positions specified by the standard (**Fig. 3**). If the colors of the LED light source are used, the image becomes too vivid (**Fig. 4**). This is because the color gamut of the LED is too wide. The Sirius employs a 3D lookup table to align the colors in the chromaticity coordinates specified by the standard and, in addition, achieves correct alignment also for faithful color reproduction of halftone. These technologies have made it possible to express the color gamut of the Adobe ® RGB standard, which is wider than the traditional sRGB standard, with regard to natural tones (**Fig. 5**).

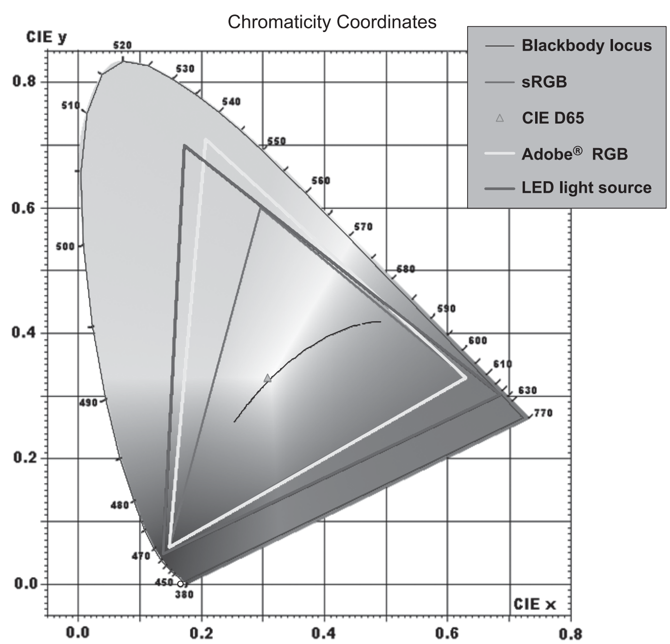

Fig. 3 xy chromaticity regions.

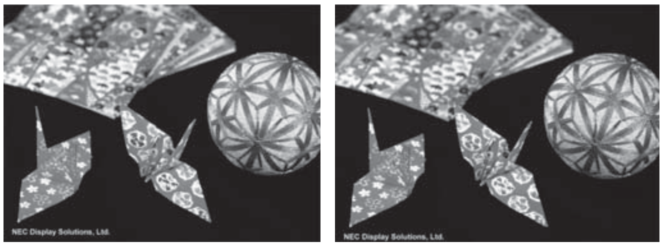

Fig. 4 Faithful color reproduction with color gamut correction (Left: before correction. Right: after correction).

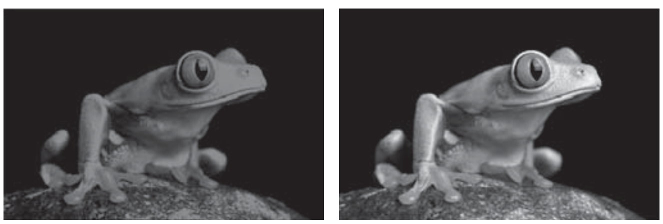

Fig. 5 Comparison of sRGB (Left) and Adobe® RGB (Right).

5. Cooling Technology

5.1 Liquid Cooling System

Since the Sirius uses multiple high-power LEDs, a special liquid-cooling system optimized for projectors is used to cool the LEDs. General projectors cool their various parts by using air-cooling fans. However, as the cooling air needs to travel via a complicated route to cool the high-power LEDs that are scattered widely in the system, the cooling efficiency deteriorates with the conventional air cooling method. With the Sirius, we reviewed the piping route and the connection of the radiator and developed a highly efficient liquid-cooling system that can process a large amount of generated heat while minimizing the increase in the system size. In general, the liquid-cooling system is not recommended for electronic devices due to problems such as liquid leakages and condensation. Some PCs adopt small-scale liquid-cooling units for the CPU, but such machines are not very common. In the present development, we applied thorough condensation countermeasures and took adequate measures to deal with the prevention of liquid leakage.

5.2 Circulating Cooling System

The Sirius employs a circulating cooling system for the LCD panel (**Fig. 6**). It feeds the air used to cool the panel to the heat exchanger through a duct and, after cooling the air, feeds it again to the panel. As this system does not take the outside air, it can protect the optical components around the panel from being contaminated. What is important in developing a system with a long service life is the dust prevention measure. The lifetime of a projector is usually defined as the period until the luminance drops by 50%. The major cause of the service life expiration is the decrease in the lamp brightness. This is usually a result of aging but another important factor causing it is the contamination of the optical components by fine dust particles in the air. For the projectors using the lamp light source, the lamps need to be replaced after about 3,000 hours. At the same time, it is also necessary to replace the air filter on the external air inlet. These maintenance operations allow the projectors with a lamp light source to maintain their brightness by reducing internal contamination. With regard to the contamination by very fine dust that cannot be blocked by the above measures, the service center cleans the inside of the system once every few times of lamp replacement.

On the other hand, the service life of the light source LEDs of the LED projectors may be as long as 30,000 hours, in which period the system requires no maintenance. However, if the dust prevention measures are inadequate, maintenance becomes necessary to deal with the reduced brightness that results from contamination of the optical components. As such a situation would spoil any advantage of the LED light source the Sirius adopts a circulatory cooling system. It does not use air filters as used by other projectors and thereby makes possible maintenance-free operation in terms of the filter replacement (Fig. 6).

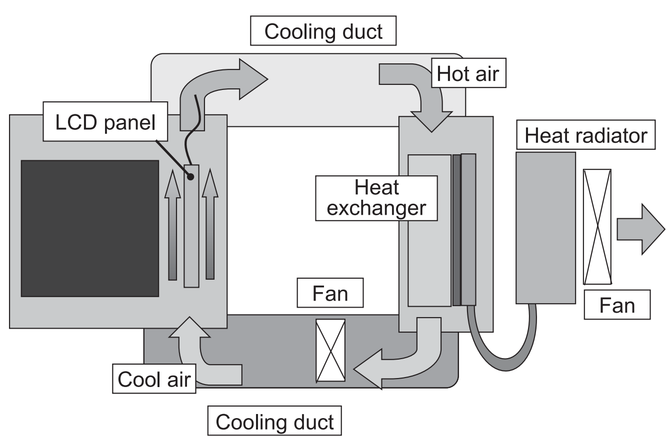

Fig. 6 Circulating cooling system.

6. Measures Regarding Variable Installation Attitudes

In general, the projectors based on the lamp light source are subjected to a restricted system installation arrangement in order to maintain stable lamp discharge characteristics. On the other hand, the LED projectors are basically not restricted in the system installation arrangement. This is a great advantage because the projectors may be required to be installed in various positions according to the usage circumstances, which include both floor installation and ceiling mounts as well as the horizontal installation that is recently popular for providing vertical projection.

The LED projector is usually capable of being installed in various situations as there are no restrictions in positioning unlike conventional lamp-based projectors. However, there is still the issue related to the use of the liquid-cooling technology as described above. A liquid-cooled system has a reservoir tank for supplementing the liquid amount reduction due to transpiration. The reservoir tank is used to store the cooling liquid but also has a space for accommodating any leaking air in order to prevent air bubbles from entering the piping. If the installation position is changed, the air inside the reservoir tank could enter the piping and might sometimes degrade the cooling efficiency. We provided the Sirius with freedom of installation position by developing an innovative reservoir tank structure which prevents air from entering the piping in any installation position.

7. Conclusion

Although LED projectors are being further developed, they have already achieved a varied color gamut and high usability that has not been possible with previous projectors.

In the future, we will continue to pursue further improvements in performance at the same time as promoting reductions in system scale and costs with the aim of making our projectors ever more satisfactory for users.

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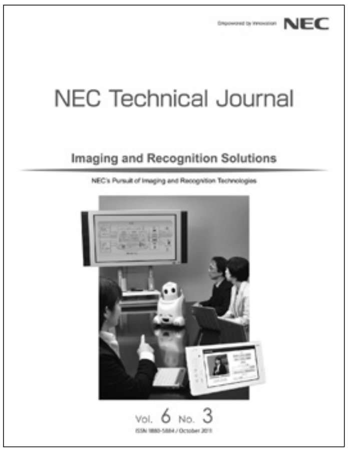

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