LED illumination

Rear-projection display systems

White paper

Introduction

Since its inception projection has been the predominant technology for displaying large, high-resolution images. Over the years projectors have evolved to keep pace with advances in computer graphics and video sources, following the trends toward ever higher resolutions and ever larger screens.

However, certain applications have always demanded higher pixel densities over larger areas than can be provided by any single fixed projector. One such application addressed in this white paper is the control room, where power and other utilities, plant processes, communication networks, transportation routes, and a host of other vital interests are monitored and controlled. These applications are often best served by a videowall composed of a multitude of rear-projection units. Such a tiled array produces a composite image with a much higher pixel count than any single projector.

Videowall Challenges

Videowalls present a number of important challenges that must be met by a projector. These primarily concern reliability, overall cost of ownership, ease of setup and maintenance of performance over time. As it turns out, all of these concerns are greatly affected by the nature of the projector's light source.

A digital projector typically uses a high-intensity discharge (HID) lamp to illuminate one or more microdisplays. In such a lamp, an arc within a glass envelope ignites a gas under high pressure containing either xenon or mercury vapor. The mercury-vapor type is the most common. The nature of an HID lamp is in stark contrast to the rest of a modern digital projector, which is comprised primarily of solid-state devices, including the microdisplay. The light source has remained stubbornly non-solid-state – until now.

Light Emitting Diodes (LEDs) have emerged as a solid-state replacement for HID lamps (see figure 1). As implemented in the Christie Entero™ LED rear-projection display systems this technology provides a number of distinct operational and performance advantages that solve many of the challenges of projection arrays in general, and videowalls in particular.

Figure 1 - LED Light Source

Operational Advantages

Operationally, the prime advantages of LEDs are high reliability and long life. For example, reliability data from LED-manufacturer Luminus Devices based on several million device-hours of testing, predict median lifetimes in excess of 50,000 hours, potentially as high as 80,000 hours, under operating conditions typical in projection applications [1]. This figure is far in excess of the expected lifetimes of HID lamps, which can vary from as low as 500 hours for some high-power Xenon lamps to as high as 10,000 hours for certain low-power, ultra-high pressure mercury-vapor lamps [2][3] .

The high reliability of LEDs directly results in a lower cost of ownership by avoiding the material and labor costs of regular lamp changes, including the cost of proper disposal of spent lamps. Since mercury-vapor lamps in particular contain mercury, an environmentally restricted substance in many countries, the environmental impact of replacing such lamps cannot be ignored.

A much higher light-source lifetime also means far less downtime of a projector in a wall due to lamp failure and replacement. The inherent reliability of LEDs could potentially mean no light-source replacement for any projector in a videowall past its useful life.

Not only are LEDs much more reliable as a light source than HID lamps, they can also potentially contribute to higher reliability in the balance of a projector's optical system, since they do not generate ultraviolet (UV) light. HID lamps, in contrast, generate a significant amount of UV light that must be removed before it enters the optics of the projector since its presence can prematurely age optical coatings and other materials, especially those based on organic compounds [4]. Of course, careful design can mitigate this issue, but projection technologies that employ polarizers, such as Liquid Crystal Display (LCD) and Liquid Crystal on Silicon (LCoS), have historically been particularly sensitive to UV [5].

In the specific case of a single-chip DLP® projector, using LEDs as a light source instead of an HID lamp enhances the reliability of the projector in yet another way. With a traditional HID lamp, a single-chip

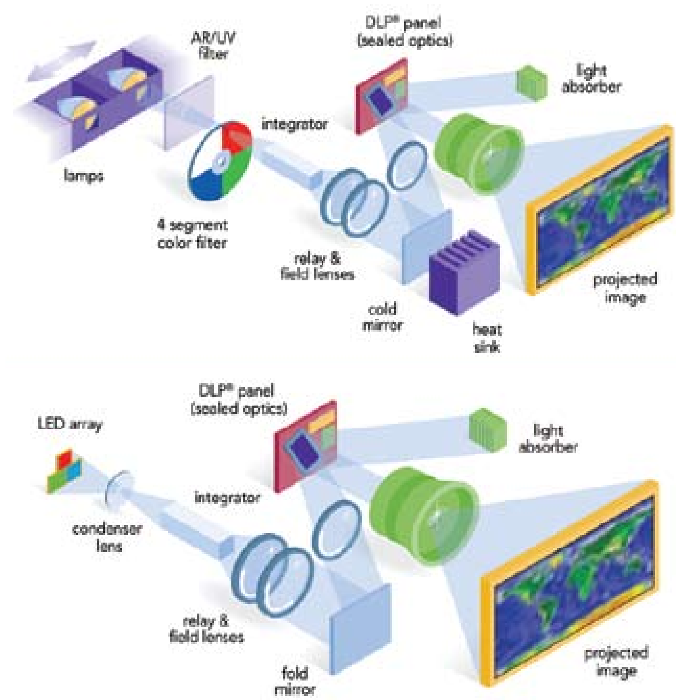

Figure 2 - Traditional lamp-based and LED-based systems compared

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DLP® system requires the use of a mechanical color wheel to cycle between the primary colors during every video frame. The wheel filters out the primary colors from the continuous spectrum of light provided by the lamp.

Unfortunately, as a moving mechanical device the color wheel is a weak point in the overall reliability of the projector. The use of LEDs completely eliminates the need for the color wheel (see figure 2). Primary colors are instead cycled electronically by switching very rapidly between the separately controlled red, green and blue LEDs, turning them on and off as required, which does not reduce their inherent reliability.

Performance Advantages

LED illumination technology provides a number of performance advantages. For one, LEDs can not only have long useful lifetimes, but assuming careful projector design they will lose relatively little brightness as they age. Long term aging data for typical devices predicts that even at maximum recommended junction temperatures a drop of only about 20% for red and blue and less than 5% for green can be expected after 20,000 hours of operation [1]. HID lamps, in comparison, typically drop quickly from their peak output within a few hundred hours and are down 50% by the end of their much shorter useful lives (by typical definition) [2]. (See figure 3)

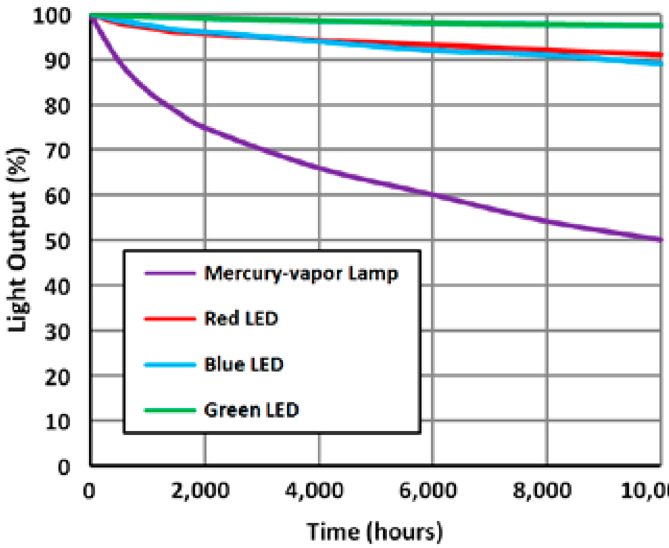

Figure 3 - Light output over time for a best-case mercury-vapor lamp and typical LEDs

A slower drop in light output results in a higher average brightness relative to peak brightness over a given length of time. More importantly for a videowall, it also makes it easier to maintain the brightness uniformity of the overall image across the videowall, since the individual tiled images will, in their uncorrected state, vary less in brightness.

Maintaining brightness uniformity across a videowall requires good control of the relative intensities of the individual projected images. Here too LEDs confer an advantage. The brightness of an LED can be electronically controlled through a wide range – potentially as high as 100% (full white to full black) with little or no change in the characteristics of the device. The range of brightness control of an HID lamp, in contrast, is typically more limited: as small as 20% for some mercury-vapor lamps and as much as 50% for xenon.

The ability to exactly control LED light output not only allows balancing of peak brightness across the projectors in a videowall, but allows exact balancing of black levels and color as well. Since LED-based projectors use separate red, green and blue LEDs with independent control of the intensity of each, any color imbalance can be easily corrected in real time, resulting in highly stable colors. With communication between projectors in the videowall, this also allows precise color matching between projectors. Furthermore, this process can be completely automated. Christie ArrayLOC™, for example, provides real-time and continuous balancing of brightness, black level and color automatically across an array of up to 128 projectors.

Color is widely considered to be the most important determinant of image quality after contrast ratio, resolution, and brightness. It is also one of LEDs greatest strengths. Each of the red, green and blue LEDs used in projectors emit a fairly narrow range of wavelengths, with typical dominant wavelengths at about 460nm for blue, 525nm for green and 625nm for red. As a result, the native gamut of an LED projector is comparatively large. As shown in Figure 4, the area of the triangle on the CIE chromaticity diagram (1931) that defines the gamut for a typical LED projector is nearly 70% larger than the gamut of the European Broadcasting Union (EBU) color space commonly used for control room displays.

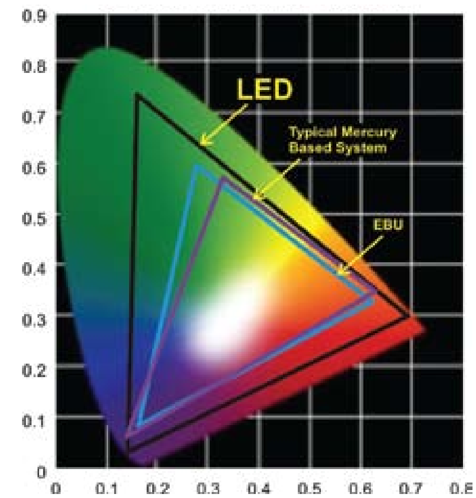

Figure 4 - LED, typical mercury-vapor and EBU gamuts compared

The larger gamut of LED illumination allows the accurate reproduction of real object colors that lie outside the spectral capabilities of conventional lamp technologies, provided that the source content has been appropriately coded. Standard color spaces such as EBU can still be accurately rendered, of course, by desaturating the primary colors.

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By virtue of the completely separate control of each primary color possible with LEDs, this can be done with little or no sacrifice to other performance parameters.

More importantly for a videowall, a large projector gamut allows a wider color space to be achieved across the entire videowall, since any common color space will by necessity be constrained to be within the color gamut area achievable by every projector. With displays that only nominally achieve the EBU color space, for example, the resultant color gamut of the videowall is likely to be smaller than the EBU gamut due to the affect of tolerances.

Last, but not least, LEDs practically eliminate the color-sequencing artifacts previously associated with single-chip DLP® projectors. The speed of the color wheel in a projector that uses an HID lamp is limited to a few hundred revolutions per second, which means that the number of times the RGB colors can be cycled every frame is also limited. Hence, the color wheel causes a color separation artifact (the so-called "rainbow" effect) that can be visible with rapid eye or head movement. For example, a white-on-black image can break up into multiple color trails.

In an LED projector, the switching of the LEDs that performs the same function as the absent color wheel occurs at such a high speed that the rate of color change is well above the flicker-fusion threshold for almost every observer. Although not everyone sees color breakup to the same extent, this is a welcome development for those who are sensitive to it.

Meeting the Challenges

Although using LEDs as light sources provides many advantages for videowalls compared to HID lamps, effectively exploiting those advantages requires overcoming a number of considerable challenges.

First, the light from an LED, both in terms of its luminous flux (raw lumens) and its spectral characteristics is dependant on the electrical current driving the device and on the device's junction temperature. In particular, both factors can shift the peak wavelength emitted by the LED, which changes the color gamut of the image [6]. Clearly, both current and junction temperature must be precisely controlled. After several years of research, Christie has developed a number of proprietary techniques for such control, resulting in multiple patents filed.

Second, junction temperature also affects both the reliability of the LEDs and how fast their light output drops over time. Hence, good thermal management and system cooling are essential to minimize temperatures, increase reliability and maintain optimum performance of the projector over time.

Finally, there is the issue of brightness. Admittedly, LEDs at this time are not capable of the high levels of light output possible with a number of mercury-vapor lamps, much less those from higher-power xenon lamps. Nevertheless, there are many applications for which the on-screen brightness currently achievable with LEDs is appropriate and for which the other image performance and operational benefits of LEDs are of greater importance. Control room videowalls are one such application.

However, spurred by the many advantages of LED illumination development of the technology has been proceeding at a rapid pace, with large increases in luminous flux over the last few years. That trend is expected to continue, which promises further increases in brightness in the coming years.

The Christie Advantage

LED illumination has already proven itself in a number of projection products, such as consumer rear-projection televisions and so-called "pocket" front-screen projectors. As the brightness of large-format LEDs such as PhlatLight®, by Luminus Devices, continues improving, many more products for an even wider range of applications are sure to appear.

However, addressing the challenges particular to control rooms requires purpose-built designs, such as the Christie Entero™ LED line of rear-projection display systems. The innovations they embody successfully exploit the advantages inherent in LED technology to provide a videowall solution that is highly reliable and virtually maintenance-free.

References:

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