IMAGE 2015 Conference

SOLID STATE, LASER HYBRID LIGHT ENGINE IN A LCOS PROJECTOR

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ABSTRACT

Solid state light sources are becoming the standard in many new aircraft simulator installations. This is mostly due to the low maintenance required on the projector and the longer life of projector and light source. This paper will discuss the JVC laser hybrid projectors being offered with regards to life cycle cost, life of the illumination system and optical components. Power versus lifetime will be brought out and the best way to optimize your visual system. Also, additional benefits from the hybrid system include IR capability for NVGs, very low speckle contrast, high dynamic range, higher brightness and lower black levels. Discussion on the latest ***IEC 60825-1:2014 ed3****, FDA guidance document on Laser Illuminated Projectors (LIPs), ICAO 9625 laser specifications and other laser safety information will be discussed. Comparisons to classical lamp based projectors for baseline will be used to determine advantages over older technologies.*

INTRODUCTION

As the demand for solid state light source engines grow, the development of the laser hybrid light source, in cooperation with the advantages of a D-ILA® LCOS engine, is now a reality for the simulation industry. For years the D-ILA LCOS has given the highest native dynamic range of any 3 chip projector. To answer the requirement for lower maintenance and stability over lamp based projectors, JVC has introduced a new series of 2K and 4K e-shift projectors that combines the performance of the LCOS with a solid state light engine to give the best of both worlds. Details of both the light engine and solid state light source will be discussed and how they relate to current regulatory requirements.

BACKGROUND

D-ILA or Direct drive Image Light Amplifier, was first introduced by JVC in 1997. While many models have been used in various simulation applications, the VS2000 was the first Visualization Series designed with full motion, level D requirements in mind. With the advent of the visible wire grid polarizers by Moxtek®[1], true contrast/dynamic range required for aircraft simulation was achieved. This was base lined in the VS2000. Prior to the VS2000, several HD2K projectors were installed in level D commercial simulators, but with its limit 2000:1 contrast ratio, there were many complaints that the blacks were not black but gray. Throughout the past 18 years, several generations of D-ILAs, both analog and digital backplanes, and evolution of the optical systems have occurred to improve performance and reduce cost.

As for the light source, historically after CRTs, the main workhorse for the projector industry was small arc gap arc lamps. Both xenon and high pressure mercury lamps have also gotten better, brighter, longer life and cheaper. Next was the solid state lighting revolution, with LED and Laser light sources going into mass production, and performance improvements over the last couple year, it is now feasible to replace the arc lamps with solid state illumination. The main reasons the simulation world are moving to solid state illumination is to reduced maintenance cost. This is twofold, 1) much longer lifetime of the solid state sources and 2) reduced calibration of visuals to maintain color and brightness tracking. The stability comes from the internal feedback system that controls the diodes that is not available on lamps.

PROJECTORS

The Visualization Series projectors have improved with each model in almost all aspects. Brightness and contrast steadily increased each year, but the largest jump came with the laser hybrid in the VS2300 and VS2500 series as seen in Figure 1 below. This is due to ability to precession align the laser hybrid light source to the optical engine and the improved uniformity of the illumination. In the manufacturing of lamps, there are minor tolerances as well as the potted assemble and housing. This coupled with an interface that also has some tolerance, which all add up and are different each time you change the lamp. With the laser hybrid, you do not need to change, as the life is 10x or more of the lamp based system.

Note the laser hybrid illumination and color management used in the VS2300 and VS2500 is trade marked by JVC as "BLU-Escent".

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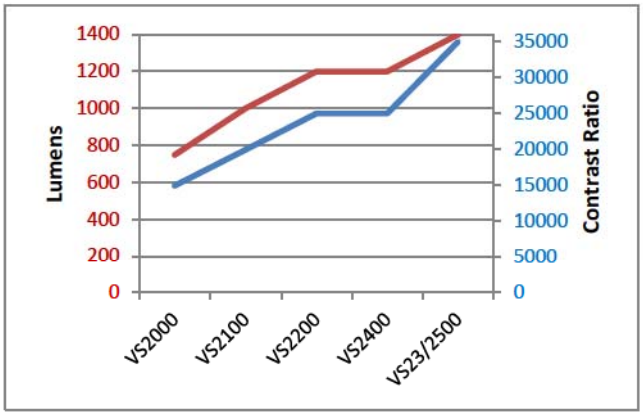

Figure 1
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D-ILA LCOS device

The heart of the projector is the imager. This is the key to high contrast ratio, life time and motion performance. Although other elements are needed to optimize the device, it is the key component.

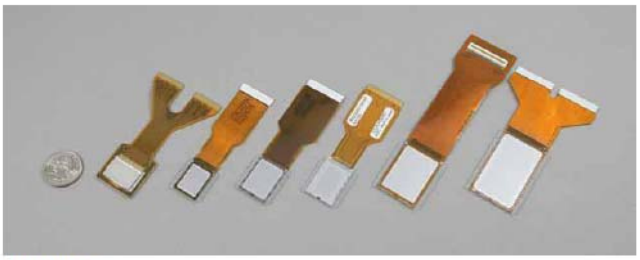

Figure 2

JVC has over 18 years' experience developing and manufacturing its Direct Drive Image Light Amplifier, also known as D-ILA. The generic term used for this device is LCOS, but a word of caution, not all LCOS are the same. With device resolutions starting from 1280x720 to 8192x4320, JVC is the leader in high resolution devices, Figure 2. For simulation, the main resolutions are the 1920x1080 for our 2K products and 4096x2400 for our 4K and 8K e-shift models. Early LCOS all had smear issues, but with today's Liquid Crystal materials, and 120 Hz drive, smear has been reduced to a 3rd order effect. JVC has always been the leader in lifetime of the device. In the core design, materials and manufacturing of the device, give the long lifetime required by simulation. For details on device construction and thermal stability, see JVC white paper, "Reliability of D-ILA Projectors" [1].
The main killer of any LCOS is the UV light, which is in all lamps. UV filters are used, but is never reduced to zero. With the blue laser used in the laser hybrid illumination, there is zero UV light emission, Figure 3, so you truly have zero UV and thus extends the life of the optical components 2-3 times over the lamp based projects. This reduces optical block change out, thus reduces overall cost and maintenance.

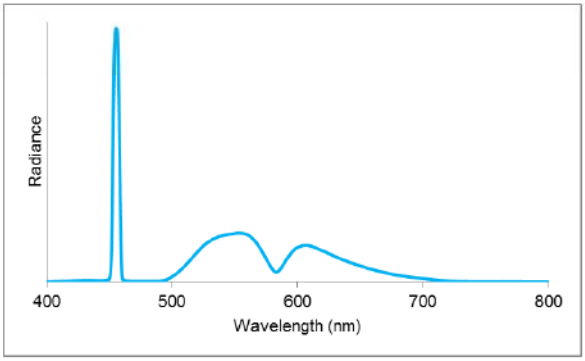

Figure 3

High Reliability over Long Operating Hours

Projectors used in a simulation or training environment are routinely used over 20 hours a day, 7 days a week. That means all components, including the projector, need to have very high reliability to be operational with minimal downtime. The BLU-Escent DLA-VS2300 and DLA-VS2500 projectors meet this requirement.
In a lamp-based projector, the lamp is the component that requires constant maintenance and regular replacement. In the laser-phosphor design of the BLU-Escent projectors, there are different lifetime concerns. These are the lifetime of the blue lasers and the phosphor coating on the wheel.

The phosphor material can see reduced conversion efficiency over time, but the main degradation mechanism is heat. Therefore, the key to longevity is proper thermal management. JVC uses an aluminum substrate for the phosphor wheel for two reasons. One, a reflective mode offers fewer optical losses for higher efficiency, and two, it offers high thermal conductivity to quickly remove heat generated in the phosphor. In addition, JVC uses a dedicated fan to keep air blowing over the phosphor wheel, figure 4, to maintain a nearly constant temperature. This reduces phosphor aging but also helps to maintain stable light output levels. Finally, JVC has designed a robust phosphor wheel using ball bearings to ensure vibration-free spinning. This means mechanical failure is unlikely, allows operation in any orientation, and even helps to maintain color balance of the light output, Figure 4.

Laser Block Unit

Phosphor wheel

Figure 4

The blue lasers are semi-conductor devices that generally degrade slowly over time. But, if one device should fail catastrophically, there are several blue lasers still operating so the projector can still continue to output light, Figure 5.

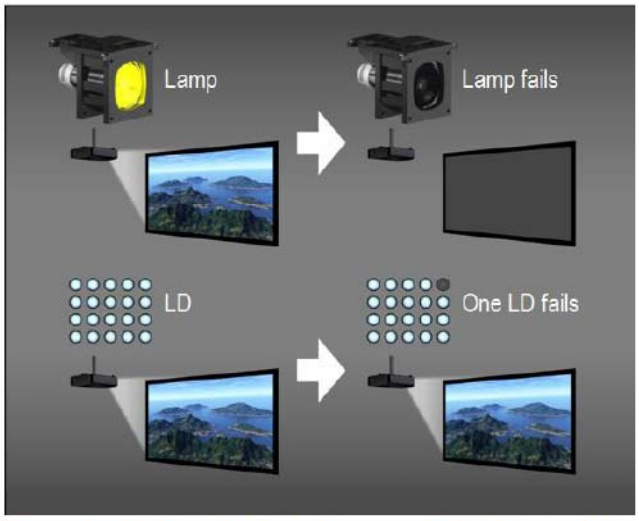

Figure 5 A Lamp Failure Causes a Dark Screen but a Laser Diode Failure only Reduces Brightness

ILLUMINATION

Figure 6 shows the optical layout of the BLU-Escent projector with reflective phosphor wheel, laser diode block and D-ILA optical block assembly.

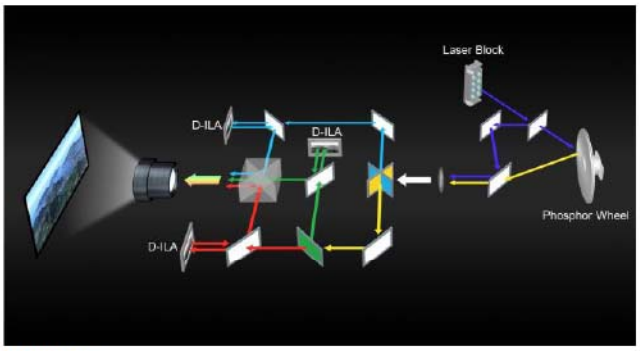

Figure 6

Very High Contrast and Dynamic Range

The JVC BLU-Escent projectors offer very high contrast and dynamic range. For simulators, that can be the difference between usable and unusable. For example, one key application is landing in fog or low light levels where pilots key on seeing runways or other lights to aid in landing. If the contrast is not high enough, the pilots cannot distinguish the lights from the background, making it difficult to see the landing lights in a CAT III scenario, compromising the simulation. The high dynamic range allows the lights to punch through the fog, giving a realistic, calligraphic like image. For nighttime or night vision goggle (NVG) operations, you must have a very low black level in your projector to provide decent contrast. The BLU-Escent projector meets this need by offering a guaranteed on/off contrast ratio of 20,000:1 and a typical level of 30,000:1. The absolute black level will vary based upon the lens, lens shift and other factors, but can be matched with proper attention. And, with such high native contrast, the black levels will be very low.

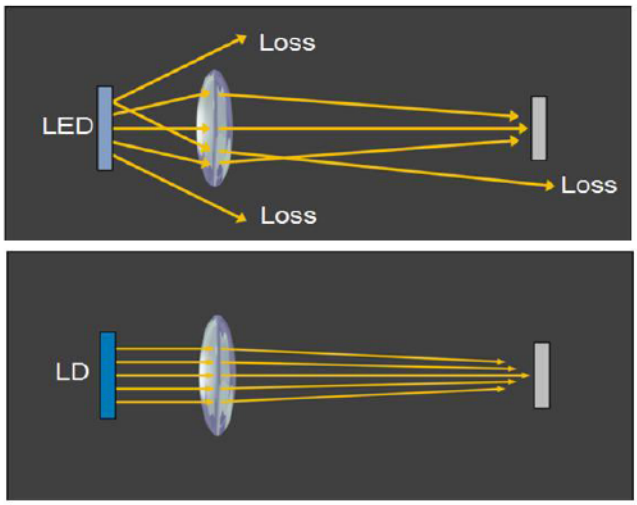

Figure 7 Collection of Light from an LED vs. a Laser Diode

Part of the reason for the high native contrast is the D-ILA panels, but the second benefit derives from the use of lasers as a light source. Lasers output light in a very narrow cone compared to LEDs or lamps, and they do so in a much smaller emitting area, better étendue. That means it is much easier to capture all of the light emitted from a laser than from an LED or lamp. The result is greater efficiency in delivering light to the D-ILA panels and higher contrast due to less stray light. Figure 7 illustrates this concept. The laser-phosphor source also emits into the infrared, Figure 8, allowing the projector to display infrared images in addition to visible band images. This is ideal for use of night vision goggles.

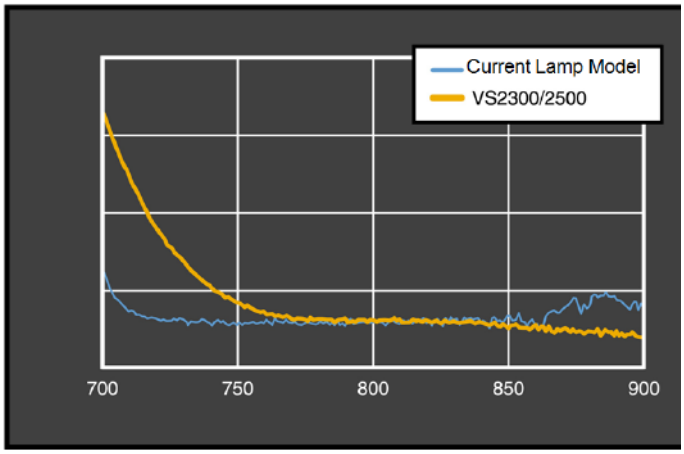

Figure 8 IR Response of JVC's BLU-Escent and Lamp-Based Projectors

Stable Brightness

The BLU-Escent DLA-VS2300 and DLA-VS2500 projectors offer a typical max brightness of 1,200 lumens, which end users have found when setup for long life and performance, is about the right level of illumination for current simulation applications. In addition to the long light source lifetime, these projectors feature Auto Intensity Mode that employs 3 dedicated sensors to adjust the light source power and color to maintain stable brightness. All light sources lose output over time, but by setting the output power to the ~50% point in the beginning, end users can maintain this level for the full lifetime of the light source. This is done by slight increases in the laser current over time to overcome efficiency losses, Figure 9 illustrates the concept. The result is that simulator training runs will not be negatively affected due to a lack of on-screen brightness. An added side benefit is the lower electrical power use, which reduces operating costs as well.

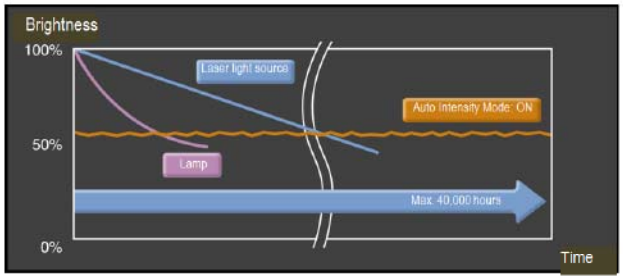

Figure 9 Light Source Brightness vs. Time

Stable and Calibrated Color Gamut

Lamp-based projectors are well known for changes in color and brightness performance over time. As the arc gap in the lamp expands, the white point and color primaries can change, requiring frequent color calibration. With the BLU-Escent projectors, the blue laser light and yellow phosphor light is very consistent and stable over time. They are also stable with fluctuations in ambient temperatures. This means they do not experience the changes that lamp-based projectors do. In addition, the BLU-Escent projectors are able to exceed the sRGB color gamut, a main requirement for most simulation applications, Figure 10. This wide color response allows for even greater saturation of colors, if needed.

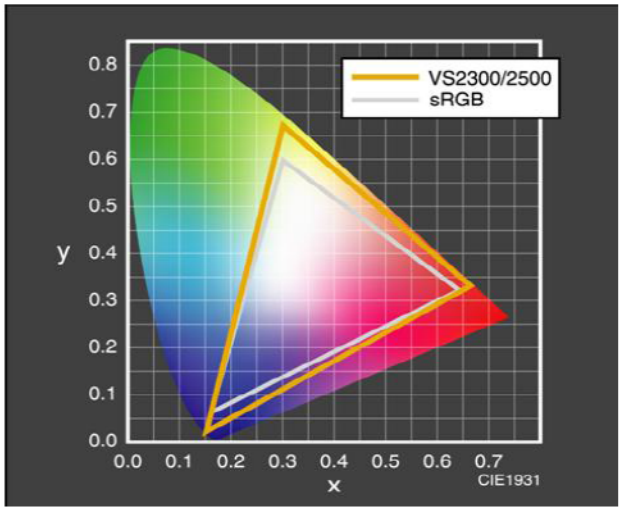

Figure 10: Color Gamut of VS2300/2500 vs. sRGB

Resolution Options

Resolution is also an important factor in projector choice. It turns out that the vast majority of simulation systems today use about three channels with 1920x1080 resolution.

Therefore, a projector with 1920x1080 resolution will satisfy the needs of most projects. The BLU-Escent DLA-VS2300 offers this 1920x1080 resolution while the DLA-VS2500 offers the same resolution panels, but with JVC's e-shift technology. This technology works by having the IG create optimized 1920 x 1080 A and B sub-frames from a 3840x2160 image buffer. The subframes are projected sequentially, optically shifted ½ pixel in both horizontal and vertical directions, alternating at a rate of 120Hz for 60Hz or 120 Hz content. The viewer's eyes blend the A & B subframes together to create an enhanced resolution image. This image gives less jaggy edges, round circles and circular light points and reduces anti-aliasing.

Flexible Mounting Orientations

Compared with conventional lamp projectors with a tilt angle limitation, BLU-Escent projectors have no limitations on orientation or tilt angle. They can be installed at any orientation through 360-degrees and even vertically, Figure 11, which is ideal for helicopter simulators which require higher vertical resolution. The rotation of the phosphor wheel remains unaffected regardless of the install angle.

Figure 11 BLU-Escent Projectors can be mounted in Any Orientation

Supporting this universal flexibility in mounting is the rugged construction and attention to the needs of the simulator community. They are ideally suited for installs on the motion base in a flight simulator, for instance.

Safety and Environmental Impact

Moving from a lamp-based projector to a solid state light source means that there is no longer the mercury in the lamp to worry about, eliminating any disposal concerns. Since the projector contains a laser source, JVC has taken special care to be sure no laser light can escape the projector housing. This is facilitated by the strong die-cast block that holds the blues lasers. This is good for thermal management and allows the projector to have a Class II laser classification. This means you follow the same safety considerations as you would with a lamp based projector. The IEC ruling, *IEC 60825-1:2014 ed3,* states that laser projector and lamp projector can be treated with the same safety requirements. The FDA has adopted the same guidance, Laser Products – Conformance with IEC 60825-1 and IEC 60601-2-22; Guidance for Industry and FDA Staff (Laser Notice No. 50) for class III lasers. The VS2300 and VS2500 are only Class II, so fall well within the same safety requirements as do lamp based projectors.

Low Cost of Operation

There are a number of costs associated with a projector used in a simulation environment. In addition to the purchase price, there are recurring costs. Since the days of CRTs, lamps have been the most common, and costly, consumable projector part. This is cost is now greatly reduced in the BLU-Escent models with illumination lifetimes up to 40,000 hours or more, depending on your optics and their efficiency. In addition, you save on the maintenance cost to replace a lamp and recalibrate the projector, and maintain calibration throughout the life of the lamp – which can be significant.
Secondly, projectors require electricity to run them and have an impact on the heating and air conditioning costs and capacity. The BLU-Escent projectors require less power than lamp-based projectors, but they now incorporate an eco-mode that can save even more electricity. Using the Hide function allows end users to run the projector in Normal or Eco mode, with the latter saving about 300 hours of operation time if used just one hour per day. Even though the light that emanates from the projector is reduced during Eco Mode, this has no effect on other projectors during adjustment or recalibration. This is especially important in an environment where multiple projectors are installed.

ICAO requirement for laser projectors

ICAO document 9625-3.6.4 on Speckle Contrast states that a laser projector will have a speckle contrast <10%. In measurements with lamp and BLU-Escent projectors we meet this requirement [2], Figure 12, and average values of white light were all <6%.

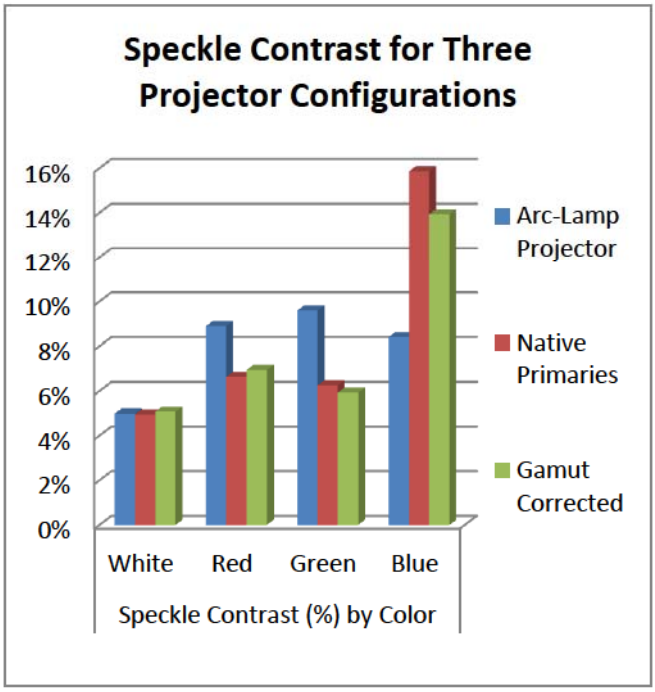

Figure 12

In addition to the ICAO requirements, VS2300 and VS2500 have been certified on level D simulation for full motion simulation. And we have met FAA FSTD Guidance Bulletin 10-01, AFS-205, Night Vision Goggle (NVG) Evaluation for Helicopter Flight Simulation Training Devices

CONCLUSIONS

The new JVC D-ILA BLU-Escent VS2300 and VS2500 have met all regulatory requirements for level D full motion systems. The solid state laser hybrid, "BLU-Escent" illumination system matched up to the high performance D-ILA optical engine gives the image quality that many have gotten used to, without the sacrifice of the brightness needed to meet minimum requirements. The internal auto calibrations system, with the long life illumination and optical system gives the reduced maintenance the simulation world is asking for.

ACKNOWLEDGMENTS

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[2] R. D. Sterling, H. Streid, K. Mihalco, 2015, "Speckle Contrast Measurements of a Laser Hybrid LCOS Projector", Proceedings of the IMAGE Conference, Dayton Ohio, 2015