

Pushing the brightness boundaries for laser phosphor projection

Technology insight

Introduction

In this white paper we will deep dive into the world of high-brightness laser phosphor (LP) projectors (10,000 lumens and up) and why this technology is suited for applications of **projectors that produce brightness levels up to 30,000 lumens**.

Laser-powered projectors are here and Barco has played a major role in bringing them to light. The seed was planted over 10 years ago. After years of R&D and advanced development, the world's first, high-brightness (55,000 lumens) laser cinema demonstration was done by Barco in early 2012 at Moody Gardens, Texas. It was the first projector that featured a complete integration of RGB light sources in the projector head. At CinemaCon 2014, Barco introduced its first commercial flagship laser projector, the DP4K-60L, a unique and revolutionary, direct-RGB (Red/Green/Blue) system incorporating 6 primary colors and Barco Laser 3D. Since then, it has quickly become the most widely deployed laser system for Premium Large Format (PLF) cinemas and has set the standard for image quality *and* greatly reduced operating expense.

And then what happened? Laser became an overnight sensation. Once cinema exhibitors realized that you could have unprecedented image quality and never have to buy (or change) a lamp again, they began asking the obvious question that everyone is now asking: "how can we convert all of our screens to laser?"

But our engineers knew that one was coming and prepared early for the "all-laser future".

On the launchpad

Barco launched laser projection in cinema because that market presented a set of requirements that could exploit and showcase the capabilities and benefits of premium projection. Since launching its line of flagship laser projectors in 2014, the pace of adoption and installation has accelerated, first driven by the need to play 3D at higher brightness levels on much bigger screens.

And then when it became clear that moviegoers universally prefer Barco laser image quality, the pace accelerated. By early 2016 more than 40 exhibitors in over 20 countries adopted over 100 Barco flagship laser projectors. At CinemaCon 2016, several pioneering exhibitors announced the first All-Laser Multiplexes and one committed to an all-laser exhibition circuit (!). At ISE 2016, Barco announced its first 4K single-chip laser phosphor projector for the fixed install and rental segments. And at Prolight+Sound 2016, Barco revealed the first laser-illuminated rental & staging projector of 30,000 lumens.

How is this possible and what does it mean for the rest of performance projection?

Why laser?

Let's review some basics. Why laser? How is it different from lamp illumination and why is it better? The simple answer is that **laser illumination combines better, more consistent image quality with much lower operating costs**. Barco originally settled on a 'direct-coupled' RGB laser architecture for its debut flagship line. Given that laser was such a new technology, the first products had to fully embody those capabilities that *only* laser could bring. Brightness levels more than twice that of the brightest Xenon projector; color and sharpness never seen before and more than 30,000 hours (7-10 years) of operation with NO lamp changes.

Lasers – like other solid-state light sources – can have incredibly **long operating lifetimes**. But lasers have a unique attribute that lamps can never achieve. Lasers have **high spatial brightness**, that is, all of the light comes from a very tiny 'facet' or 'beamline' which spreads very little. This is what enables so much more light to get to the screen. Moreover, the laser engine produces only RGB light, none of which needs to be blocked or filtered. This improves nearly all projector performance parameters, from color saturation to contrast – from wider color gamut to higher wall plug efficiency.

BARCO

Visibly yours

It was clear from the start that Barco's flagship RGB laser projectors were the perfect solution for premium large format theaters, bigger screens and brighter 3D, but what about all the other theater types and screen sizes? Barco's advanced **Laser Phosphor (LP)** illumination technology would rapidly become the solution for many of these other, wide-ranging requirements.

Why laser phosphor?

All projectors could benefit from better, more consistent image quality and reduced total cost of ownership. However, whether for cinema or for other application segments, the balance between performance and TCO requirements varies widely. Once our pioneer laser cinema customers gained experience with the flagship line, there was no turning back. They wanted laser solutions for both new builds and existing theaters, for their complete range of screen sizes and types. And these requirements quickly grew to include laser-illuminated solutions for large venue, simulation, visualization, projection mapping, rental & staging, even business projectors, with brightness levels ranging from 5 to 30+ klm.

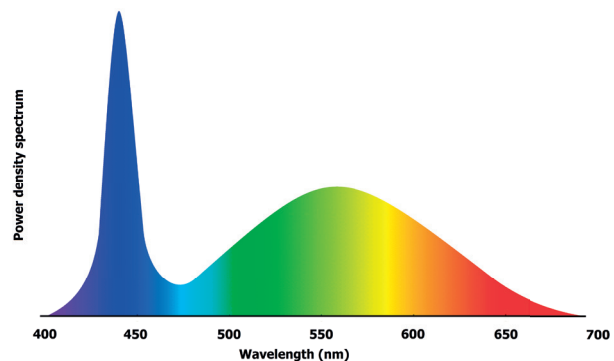
Barco's advanced laser phosphor illumination was the answer for any application that required **superior image quality and consistency** but that would also **lower acquisition cost and much lower operating cost – that is, TCO**. This novel application of a mature laser technology provides a 'platform' light source that combines lamp-beating, high-brightness lifetimes with industry-leading efficiency as measured in lumens per wall plug watt. Furthermore, it can be applied to a wide range of brightness levels, color spaces, form factors and installation environments.

How does laser phosphor work?

Most people know the LED light bulbs that are now rapidly replacing incandescent light bulbs in our houses. This global trend of using blue LEDs combined with 'yellow' phosphors to generate a white light sparked the idea of using phosphors in combination with blue lasers to generate a white (RGB?) light source that can be used in projectors.

To generate white light in a projector, one needs three primary colors: Red, Green and Blue. In the 'direct-coupled' RGB laser architecture, separate red, green and blue lasers are used. However, blue lasers are far less costly than green and red lasers, mainly because of the semiconductor materials used and their significantly larger production volumes. If you combine this with

the much higher efficiency of blue lasers compared to red and green lasers, it makes sense to use only blue lasers. But how do you create green and red light from only blue lasers?



Here phosphors come into play. If a specially designed phosphor is illuminated or 'pumped' by blue lasers, it converts the blue light into a broadband green/yellow/red light. One can filter the green and red part of the broadband light by blocking the small yellow portion. In this way the required red, green and blue light is generated all by blue lasers.

Barco has been able to advance projector cooling and optics technology to create the world's brightest events projectors with laser phosphor light sources – up to a stunning 30,000lm! Laser Phosphor light sources are also lighting bright cinema projectors – producing 20,000+ lm. More yellow light needs to be filtered out to achieve the DCI P3 color requirements and to display more saturated green and red primary colors.

Optics

First, the optics. One of the benefits of RGB lasers not present in conversion from laser light to phosphor output is **maximum spatial brightness**. The light comes out of the phosphor the way light comes out of a lamp, in all directions. However, as the lasers light can be focused down to a very small spot, the light that comes out of the phosphor is still very bright. With appropriate optics, a very high percentage of the light can be used, with high transmission through the projector. By applying LP to projectors with larger chips – the amount of light accepted is increased further and consequently – overall lumen output is increased.

So 'optimum optics' ensure that we have an efficient LP light source + projector combination for all three primary colors.

Cooling

How about lifetime? **Laser lifetime** is all about cooling. Blue lasers are efficient and so have the lowest cooling requirements compared to RED and GREEN lasers, another benefit of going 'all BLUE'. Optimum cooling of the lasers and phosphor material does **four good things**.

- Maximizes laser device power output
- Maximizes laser and phosphor reliability
- Maximizes laser and phosphor lifetime
- Maximizes primaries and White point color stability over time

By optimizing cooling and installation environment, Barco LP light source lifetimes of more than 30,000 hours can be achieved with very little brightness roll-off or drop over time.

A few numbers

Enough about concepts, physics, optics and thermodynamics – what is the bottom line? Barco just introduced and demonstrated the world's brightest DCI-compliant laser phosphor projector, the DC2K-20CLP. Not just a smidge brighter, but two to three times brighter than other models. At 20,000 DCI lumens, it is not only the brightest LP Cinema projector but at 7.0 lumens per wall plug watt, it produces 100% more lumens per wall plug watt than a comparable Xenon projector... with a *new* lamp. Or if you prefer, it requires **50% less wall plug power for equivalent lumens**.

At 2,400:1 it has higher contrast. Better uniformity – more than 80% in the corners – instant dimming down to 30% of maximum; almost no brightness roll-off and it dissipates only 6,344 BTU/hour, about less than half that of an equivalent Xenon system.

Optimization and adaptation

When Barco introduced its flagship laser to the cinema market two years ago, a lot of exhibitors and professional AV & Rental companies asked when laser would be available for *all their screens*. At that time, the LP technology was still under development, but Barco had sufficient confidence to promise **new LP projectors and field retrofit kits** for Barco cinema as well as **fixed AV install and Rental** projectors.

By mid 2017, Barco customers will be able to optimize their new builds or laser upgrades with RGB flagship 4K models, with brightness levels ranging from 20,000 up to 60,000 lumens and 2K and 4K LP models with brightness levels ranging from 6,000 to 30,000 lumens, available as new LP projectors or as LP field-retrofit kits.

Both technologies are 'inside the box' architectures, with all the laser devices safely interlocked inside the projector chassis. The blue laser pumped phosphor engines are so small, they fit right into where the lamp house used to go, direct coupling providing the most efficient delivery of light.

Thus far, Barco has concentrated its laser projection development on cinema, giving it a development focus and a huge market lead. Now it is adapting LP technology to other markets and applications with diverse primary and secondary requirements. The LP platform is being adapted very rapidly across a wide range of segments. By using the appropriate trade-offs between brightness, lifetime and cooling, Barco develops products fit for specific markets. Barco recently introduced the HDF-W30LP *FLEX*, a rugged and modular WUXGA events model that just broke the 30,000 lumen barrier for LP.

Meanwhile, another tradeoff is being optimized – using LP technology to dramatically increase the brightness of *single-chip* DLP® models, eliminating two chips and a color splitting prism. Using blue laser power in time sequential mode, ALL lasers can be utilized all the time to produce RGB primaries sequentially. The F90 1-chip 4K projector produces an amazing 13,000 lumens, again, about two to three times brighter than competitive models with 4K resolution and laser-phosphor illumination.

² <http://www.pcmag.com/article2/0,2817,2357669,00.asp>

Future advances

Pumping phosphors with blue *light* is not new, but its application to performance projection is relatively recent. Barco carefully studied the technology and its supply chain and developed a range of new and retrofit LP solutions for cinema. Then it started to adapt and optimize the technology, first for relatively low lumen (6,000) professional business and events projectors. But this year, some startling advances in lumen output, performance, and flexibility were introduced.

Higher power, higher efficiency laser devices will reduce the size, weight, and form factor for a given lumen level.

Advances in phosphor technology may widen color gamut further and/or increase lumens for a given color gamut.

New application segments

As costs per lumen-hour come down, new high duty-cycle applications will emerge for laser projection. The combination of lamp-less, and more importantly, lamp-change-less operation, dramatically reduced power consumption and over 30,000 hour lifetime will make LP projectors a good choice for dramatic signage, large scale video art, lobby displays, flexible retail and advertising setups and other high-end projection-based image displays that look more like the cinema than a grid of flat panel display rectangles.

Summary

Barco is the global technology and market leader in cinema with over 55,000 screens lit. Barco was the first to demonstrate and commercialize 55k+ lumen cinema projectors. It is now the leader in laser cinema with more than 100 flagship systems deployed in over 20 countries – enabling the twin benefits of unprecedented image quality and dramatically reduced operating costs.

In summary, Barco's laser phosphor technology is also taking the lead, in cinema and many other performance segments. Barco laser phosphor combines the lowest TCO with high-lumen output, wider color gamut, and flexible deployment. The highest DCI brightness at 20,000 lumens; highest rec. 709 brightness at 30,000 lumens; longest lifetime; unlimited orientation options; 3 or 1 chip designs; 2K *and* 4K. More Barco innovations will be introduced in the near future, showing an even broader range of Barco LP capabilities.

In other professional markets, like Virtual Reality, Rental and Staging, Control Rooms, business projectors and more, Barco is developing the laser or laser phosphor products that are optimized for the varied requirements of these segments. With the roll-out of the brightest, most efficient laser phosphor projectors in all segments of the industry to complement its RGB lines, Barco has demonstrated a strategic commitment to solid-state illumination; to outstanding image quality; to the elimination of repetitive and wasteful lamp replacement and to a massive reduction in projector power consumption.

Brighter, better images at lower cost. It's just physics, optics and thermal management. Yup, that's all it is...