Barco | White paper

Laser light source lifetime – 100,000 hours, anyone?

Will it rain in LA next summer?

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Introduction

Laser projection in cinema is becoming mainstream – cinemas have already announced large deals involving thousands of laser-illuminated projectors, and plenty of others are silently renewing their projection fleets with the latest laser projector models. Hundreds of 'all-laser multiplexes', entire cinemas that operate solely using laser projection, have been around for several years. This is an indication that the technology has matured, and that cinema exhibitors are now trusting it.

Laser technology does away with lamps entirely, which brings huge operational cost savings and operational simplicity to cinema chains. In addition, laser technology can also improve cinema presentation — no lamp flicker, better uniformity, and a much more constant brightness output. These improvements lead to a high-quality and consistent moviegoer experience. However, the lifetime of lasers is becoming a hotly debated topic on the market – with some manufacturers stating 20,000 hours, and some stating numbers as high as 75,000 hours. How can that be? Aren't we all bound by the same laws of physics, and are we all drawing the same line between science and marketing?

Facts about laser lifetime

Since the invention of lasers in 1960s, there has been a constant innovation and improvement in laser materials, packaging and processes to make laser components smaller, more efficient, brighter and more durable. Lasers first found their way into projection in 2010, when the first consumer projector using lasers as part of the illumination source was launched. Since then, there has been a rapid development of laser illumination technology for projection, and the technology has been scaled for larger screen sizes such as those used in cinema. Barco first showed a 55,000 lumen RGB cinema projector in 2012, and since then, there has been a revolution of models, technologies and applications. Each new generation learns from the previous, and the performance of and confidence in laser has grown.

What did we learn in the meantime regarding the **lifetime performance of lasers**?

The first thing is that laser light source brightness slowly decreases over time. This behavior is present in all light-emitting technologies, including LED luminaires and Xenon lamps in projection. As the lasers age, they become less efficient, and at a certain moment in the future, they reach a point specified as 'end of life' (EOL). Analogous with lamps, this is the moment in time when the laser brightness output has reduced by 50% from the initial brightness. It does not say that the laser will just stop working in the following hour; it is a statistical average of the performance – some lasers will last a shorter period, some longer, but on average, it's safe to assume that this is the end of the economic usage time of the laser light source.

We must stress, however, that **the pace of brightness decrease with lasers is *much* slower than what even the best lamp could achieve**, which is a key value proposition of laser illumination for projectors.

Also important are the ***factors* determining the lifetime behavior** of the laser light source: **ambient humidity**, **temperature**, but most importantly, the **driving level of the lasers** (linked to the electrical current flowing through the laser diode). The diode temperature is determined by the cooling capacity and type of cooling, and also by the ambient temperature, filter cleanliness and other factors. The higher the temperature or the driving level, the faster the pace of brightness decrease.

Thirdly, like anything else in this world, **lasers don't last forever**. The lasing material is typically encapsulated in a 'can' and then several of these cans are mounted in a 'bank'. The whole manufacturing process requires advanced engineering similar to that of electronics. While laser lifetime prediction models already encompass many short- and long-term effects within the diode, the long-term effects on materials (linked to usage, heat endurance, material fatigue etc.) are difficult to model and are not part of this analysis.

Facts about laser lifetime
• Laser brightness decreases slowly over time – but much slower than any lamp; • Lower temperature and driving levels (current) reduce the pace of brightness decrease and prolong the laser lifetime; • Lifetime models take into account many laser diode effects, but just like any piece of electronic equipment, lasers will not last forever.

Modeling laser lifetime

Based on knowledge of laser physics, input from suppliers, as well as in-house and field performance tests, Barco has devised laser lifetime models that take the drive current (in a mix of 2D and 3D presentation) and temperature into account to simulate the brightness decrease and EOL performance of laser diodes used in our projectors.

How do laser lifetime models work?

Based on the required screen size, gain, and screen luminance (foot-lambert) specification, we can calculate the requested initial dimming level for a certain projector illuminating that screen. From here, we can determine the actual drive level for each laser component. The expected ambient temperature is also translated to the laser temperature, since we're in control of our cooling mechanism and performance. Given these two parameters, we can calculate the expected brightness decrease of the laser light source over time.

Laser projector driving modes

There are two modes that are relevant for laser projectors: the ‘constant driving’ mode, and the ‘Constant Light Output’ (CLO) mode. As you will see below, the constant driving mode is relevant for business or commercial projectors. The CLO mode is the one that’s truly relevant for cinema.

In the **constant driving** mode, you would set the projector to a certain power (drive) level (say 80% of maximum, resulting in a certain amperage through the laser) and never touch it again. The lasers will always be driven at that amperage, and no correction for brightness or color is applied over time. Like with lamps, the projector brightness will decrease over time. The lower you set the initial drive level, the slower the decay will be, of course. However, this mode has one problem – **color shift over time due to *differential aging***. Because each laser (red, green or blue) has a different aging speed, the image white point will start shifting. In the cinema world, such a case will soon demand correction to maintain the DCI image performance requirements. In short, this mode is not advisable for real-world cinema operations – brightness and color correction will be needed, which leads us to the second mode.

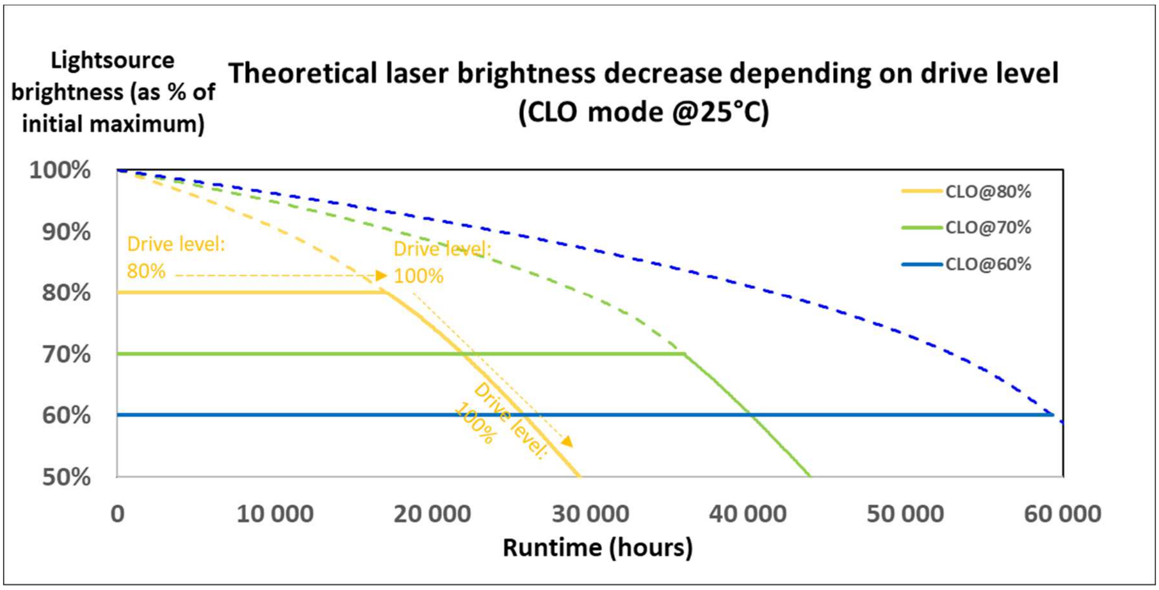
The second mode – **Constant Light Output** (CLO) - is a Barco projector feature. It’s a self-calibration mode that keeps the light output constant and can also correct for color shift over time. Upon installation, you would set the projector light source to a certain brightness level to reach the required screen luminance and DCI white point. This initial brightness level is lower than 100%, in order to provide sufficient brightness margin to perform corrections over time. Then, the internal mechanism takes over and as the light source slowly ages over time, the laser power is slowly increased as a means of compensation. In this way the brightness and DCI white point can be kept constant over a long period of time (CLO runtime), and after that, well… the driving has reached 100% and the brightness output will start decreasing as long as there is juice left. Color correction, of course, can still take place.

What do the models say?

In the figure below, you can see a simulation of the light source brightness for three target output levels in CLO mode.

The initial laser source drive level in these three cases is 60, 70, and 80%, respectively. The full lines represent the produced brightness out of the light source in CLO mode. It’s kept constant until it reaches the “CLO runtime” point, after which the output brightness cannot be kept constant any longer and starts to drop. The dotted lines represent the maximum possible output of the light source at any given moment.

As you can see, the **initial driving level has an immense impact on the speed of the brightness decrease and expected lifetime**. We don’t recommend driving the projectors at full power (100%) from the very beginning as the brightness can only decrease, and one will never have constant brightness. Also, in this case, the time to 50% of initial brightness will be much shorter than in CLO modes that start at more moderate initial drive levels. As you can also see, driving the lasers at a sufficiently low initial levels can potentially add tens of thousands of hours to the light source operation period.



Reality

That's what the models have to say. But what about in reality?

Barco first introduced laser projectors to the market in 2014, and the quality and performance of our models has been confirmed in the real world.

What this experience has taught us is that there is an additional angle to keep in mind when matching calculations with real-life cinema operations. When installing a laser projector in the field, there are **different factors to consider**:

- **cleanliness of the projection booth and the filters**: dirty filters result in less efficient cooling and thus shorter lifetime;
- **actual screen gain and screen deterioration over time**: since the achieved screen luminance (foot-lambert) is a direct result of the screen gain, having a gain lower than specified will result in running the projector at higher levels, impacting the lifetime (the opposite also holds true);
- **measurement location on the screen**: the lifetime calculation takes the screen reflection into account in the hotspot (location with maximum gain). However, the screen measurement location is typically in the screen center, which does not always coincide with the hotspot (this depends on your location in the auditorium), resulting in lower reflectance and a higher laser drive level;
- **port window transparency, aging, and dust**: The calculation of screen brightness considers a certain port window transparency. If this value is different in the field, or if dust has accumulated, it might result in a different loss factor, which will impact the laser drive level needed to reach the screen foot-lambert target.

All these factors can adversely impact the calculated lifetime if they result in driving the projector at higher levels than estimated. Knowing these factors up front will help you more accurately estimate the lifetime and make a better projector choice for the cinema. Once **in the field**, the **best indicator for projector lifetime is the actual installed drive level** (and average booth temperature).

How about in the long term? The laser performance over a time period of 5 to 6 years is well understood and does not require too many assumptions to model (as long as there is a good link between the installation parameters and modeling approach). The same models and performance can be confidently extended to a period of about 40,000 hours. **The longer we project into the future however, the more difficult it is to predict**. Compare this to the weather forecast. Short-term weather can be reliably modeled and predicted. Predicting the actual weather for next year is a different thing. We can agree that it probably won't snow in the desert or be 40°C in the Arctic – but the range of possible outcomes is pretty large. There are the long-term effects mentioned above that might kick in at longer time scales (compare this to storms, earthquakes, wildfires and other effects in our weather analogy), and this is where the models fall short.

Be critical

It took Barco time and experience to develop and perfect laser technology for all projection markets, including cinema. During this time, we learned much ourselves, and we are passing this knowledge on to our customers in order to set appropriate expectations. Critical customer questions have helped us understand the bigger picture surrounding laser lifetime modeling. We discovered that there are many angles to consider when it comes to the brightness performance of a laser projector over time – a single number (e.g. 50,000 hours) is not at all sufficient.

So, **when discussing laser projection technology, ask questions like**:

- What is the remaining brightness after the indicated lifetime period?
- Is this brightness measured out of the lens, or out of the light source?
- Is the brightness output automatically compensated for over time (like in a CLO mode), or is the projector allowed to just drop in brightness?
- What are the booth temperature conditions needed to reach this lifetime figure?
- What is the allowed initial driving condition of the projector (at what percentage of maximum power is the projector allowed to run in order to reach the indicated lifetime)?
- Is this claim covered by any warranty (e.g. replacing the light source if the lifetime is not reached)?

Such questions (and the answers you get) will not only help you paint a clearer picture of different lifetime claims, but hopefully will also help the industry to come with a more consistent and diligent way of defining long-term lifetime performance of laser projectors.

Summary

Laser projection is widely used in the cinema market today and is rightfully claiming its place on the projection throne. Barco's long-term development and field experience with laser projection results in projectors that eliminate the hurdle and cost of lamp swaps, offer much higher electrical efficiency (lower electricity use and A/C cost), generate better and more constant image quality, and have very long economic lifetimes.

At the same time, the potential of the laser lifetime extension is leading some to claim (and believe) that lasers will endure stress for 50, 75 or even 100,000 hours of operation.

The short comment on this: they may or they may not. Based on lifetime models, given a sufficiently low temperature and initial drive current, we can indeed simulate lifetimes that extend to such long periods. However, the further in the future we look, the more difficult it is to reliably predict what will happen. Someone might claim that it will rain all summer long in Belgium or that it won't rain a single day in Los Angeles in 2021. It might. But as far as science goes, there's no reliable grounds for such a claim. Barco has had laser projectors on the cinema market since 2014 – our testing and field reports so far support our lifetime models, giving us the confidence to estimate lifetime performance for a practical time horizon of 40,000 hours.

Key messages

- Barco has had laser projectors in the field since 2014.
- Our laser lifetime models are based on supplier data and field experience.
- Barco can provide lifetime estimates for Constant Light Output modes for as long as 40,000 hours of operation.
- Lifetime claims beyond that are less predictable, given no field experience.