CHRISTIE®

WHITE PAPER

ENERGY EFFICIENCY

of solid-state laser-illuminated projection technologies vs traditional analog lamp-based systems

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Innovation in every frame™

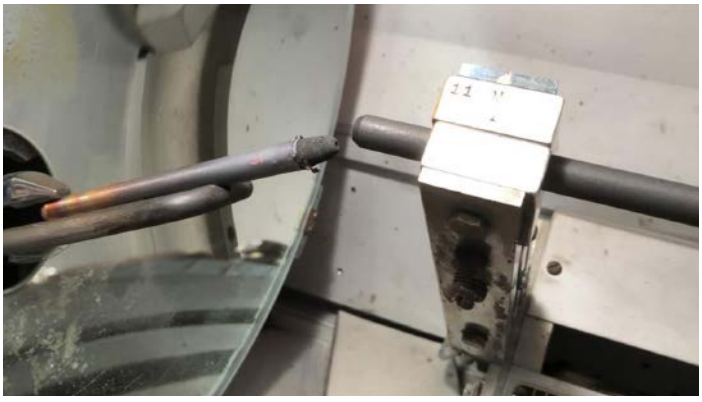
Background

This paper covers certain fundamentals of illumination technology used in image projection applications, with a focus on commercial cinema exhibition. Image display systems in cinemas function by projecting light onto a relatively large surface that subsequently reflects the light back. Traditionally these projection systems primarily depended on illumination technologies that pass an electrical current between an anode and a cathode. Electrical current jumping between these two points causes a release of photons that emits light. This technique has been used for more than a century in cinemas worldwide to project images onto a surface.

Carbon arc technology

Early systems used crude and electrically inefficient "carbon arc" technologies to create this sustained spark between two rods of graphite carbon. Creating this "arc" required massive amounts of voltage and current, usually around 17,000 watts to produce 10,000 lumens* of light – anywhere from 1.5 to 2 lm/W. Carbon arc technology produced a steady source of illumination, but was dirty, inefficient, and high maintenance; each carbon rod only lasted about 4 hours and had to be manually replaced by an operator at regular intervals.

**The lumen (symbol: lm) is the unit of luminous flux; a measure of the total quantity of visible light emitted by a source per unit of time*



Pictured: A close view of two carbon rods used in carbon arc technology
Source: Model, B. (2019, August 12) Shedding Some Light on Classic 35mm Film Projection. SilentFilmMusic.com/carbon-arc

Pictured: Carbon arc, super bright, viewed safely through tinted glass
Source: Model, B. (2019, August 12) Shedding Some Light on Classic 35mm Film Projection. SilentFilmMusic.com/carbon-arc

Arc gap Xenon illumination

In the 1980s, this technology transitioned to a cleaner, more efficient, and lower-maintenance system by encapsulating "arc gap" illumination in a glass enclosure filled with pressurized Xenon gas. Arc gap technology passes electricity between an anode and cathode through ionized Xenon gas at high pressure to produce a bright white light that simulates sunlight. Compared to carbon arc, the light produced by arc gap technology in Xenon lamps is of higher quality, and projectors that use this technology have a longer lifetime, are more energy efficient, and require less maintenance. These projectors represent a considerable advancement in technology that had seen no significant improvements for decades. In terms of system efficiency, Xenon-based projectors achieve more than twice the operational efficiency of carbon arc, producing anywhere from 3 to 4.5 lm/W. Pair that with the high-quality image they produce onscreen and it's no wonder that most cinemas worldwide continue to operate with Xenon-based projection to this day.

Pictured: Xenon lamps in use in a cinema application

The advent of solid-state laser illumination

In the early 2000s, solid-state laser light sources were starting to become available for projection applications – but were only available at low power levels and in limited wavelengths. Green lasers were especially expensive and inefficient, as they required a power-inefficient frequency doubling from infrared (IR) lasers. It wasn't until around 2015 that lasers able to support the quality, lifetime, power levels, and specific wavelengths that cinema applications require became more widely available.

The latest revolution in projection illumination uses direct-emitting laser diodes. A limitation of both carbon arc and arc gap technologies is that they generate light in an arc that's neither uniform nor coherent but must then be focused. Lasers are superior because they are easily focused into an exact, precise optical path.

Laser phosphor

Laser illumination technology for cinema has evolved into two major architectures, with multiple derivatives produced to fit specific market needs. For example, in its most basic form that uses blue laser devices only, laser phosphor (LaPh) is an entry-level cinema technology that eliminates the need for lamp changes but offers a similar lamp-like performance. LaPh illumination offers a modest efficiency improvement of 4-5 lm/W over Xenon. As LaPh technology evolves with the addition of red lasers – and in some cases green, as "green-augmented laser phosphor" – system efficiencies continue to increase to 5-8 lm/W. These enhancements also offer improved color reproduction but still retain lamp-like performance.

RGB pure laser

Christie's implementation of these solid-state devices - known as RealLaser today – started in 2015 when significant evolutionary changes to green laser devices became mature enough to productize. These changes specifically enable the use of direct-emitting green lasers and eliminate the need to use highly inefficient IR (infrared) lasers.

Christie has continued to evolve this technology into our RealLaser portfolio of cinema projectors that use RGB pure laser illumination, which outperforms other illumination platforms in terms of quality, and yield other great benefits too. Implementing these laser devices dramatically improves system efficiency, with light collected using precision collection optics.

Laser Optical System (LOS)

These design considerations and implementations gave birth to the heart of RealLaser projection: the Laser Optical System (LOS). RealLaser projectors now use second-generation LOS systems (LOSv2) that have been improved to decrease the power required to operate these devices.

We'll explore this operational efficiency, the impact of efficiency on the cost of operation, and the environmental impact of RGB pure laser – specifically Christie RealLaser – over other technologies and implementations.

Power efficiency

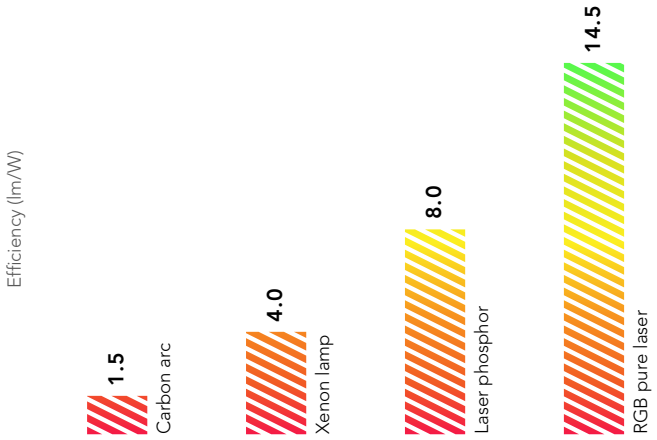
Energy has been a primary design consideration for decades of cinema projector manufacturing at Christie. From the power supply and lamp technology to the patented relay optics design of our projectors, we understand exhibitors' stringent business needs and the long-term investment that digital cinema projection requires.

These considerations are more important than ever today thanks to multiple factors, including environmental impact and the geopolitical instability that's causing short- and long-term volatility in global energy prices. With our latest RealLaser technology, we offer more than 300% improvement in energy efficiency over lamp-based projection, combined with the unmatched presentation quality of RGB pure laser illumination.

Measuring operational efficiency

How do we measure operational efficiency for cinema projection? As the ratio between the rated brightness output – measured in lumens or "lm" – and wall-plug power consumption – measured in watts or "W". The resulting efficiency parameter is a term known as "lumens-per-watt" or "lm/W" – something you'll see highlighted on every projector specification sheet.

Efficiency comparisons
through the evolution of illumination types



Christie CineLife+ RealLaser projectors: Unmatched efficiency and performance

Projector	Maximum brightness (lumens)	Resolution	Efficiency (lm/W)	Equivalent lamp-based efficiency (lm/W)
CP4455-RGB	57,000	4K	12.3	3.9
CP4445-RGB	47,000	4K	11.2	3.9
CP4435-RGB	35,000	4K	14.5	3.9
CP4425-RGB	26,000	4K	14.1	4.9
CP4420-RGB	20,000	4K	12.9	4.9
CP4415-RGB	15,000	4K	11.9	4.7
CP2420-RGB	20,000	2K	12.9	4.9
CP2415-RGB	15,000	2K	12.7	4.5

Cost of operation and ownership

With the yearly rise and constant fluctuations of energy costs worldwide, one of the key considerations in creating new projection technologies is the cost of operation. With the improvements made to our laser-based light sources, the operational efficiency of RealLaser projectors continues to improve, which translates to operational cost savings for our customers.

We can break down the cost of operation as the kW/h costs to run the projector, which varies significantly by location.

Christie CineLife+ RealLaser projectors: Cost of operation

Projector	Maximum brightness (lumens)	Total power consumption (k Wh)	Cost of operation over 10 years in USD$*
CP4455-RGB	57,000	4.630	$40,559
CP4445-RGB	47,000	4.185	$36,661
CP4435-RGB	35,000	2.416	$21,164
CP4425-RGB	26,000	1.840	$16,118
CP4420-RGB	20,000	1.555	$13,622
CP4415-RGB	15,000	1.265	$11,081
CP2420-RGB	20,000	1.545	$13,534
CP2415-RGB	15,000	1.180	$10,337

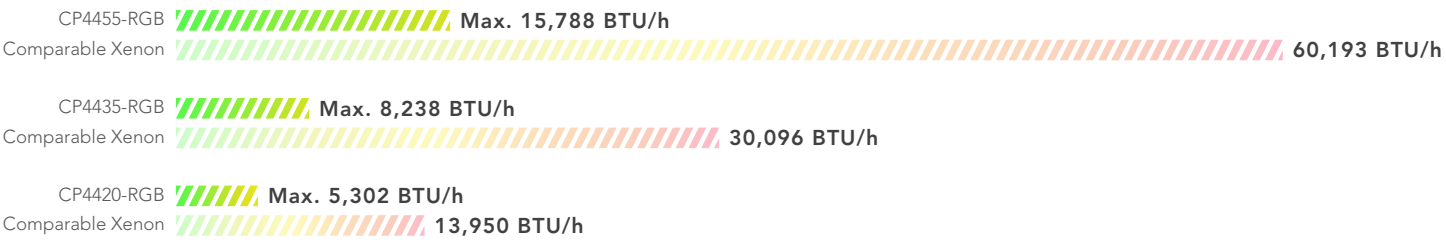
*Based on an average of USD$0.30 per kWh running 8 hours per day

In addition, because our projectors run more efficiently, they don't require as much heat extraction as Xenon projectors or competitive units. While heat extraction (measured in BTU/hr) varies depending on environmental conditions, including ambient temperature and humidity, an RGB laser projector generates on average less than one-third of the heat load (also measured in BTU/hr) of a Xenon lamp projector with comparable brightness. The improved efficiency of our RealLaser lineup means that most of our systems don't require extensive heat-extraction setups or excess reconditioning of booth air – another example of the effect of significant energy efficiency that offers a positive impact on both the environment and the bottom line.

Christie CineLife+ RealLaser projectors: Heat load compared to Xenon

Projector	Max. BTU/h heat load	Comparable Xenon BTU/h heat load (scaled by brightness)
CP4455-RGB	15,788	60,193
CP4445-RGB	14,270	39,833
CP4435-RGB	8,238	30,096
CP4425-RGB	6,274	23,020
CP4420-RGB	5,302	13,950
CP4415-RGB	4,313	14,069
CP2420-RGB	5,268	13,950
CP2415-RGB	4,023	10,912

Examples of RGB pure laser heat load
compared to equivalent brightness lamp-based projectors



Comparable Xenon BTU/h heat loads scaled by brightness

Environmental impact – CO_2 emissions

Another way to look at projector efficiency is by its carbon footprint. We designed our CineLife+ RealLaser projectors to be backwards- and cross-model compatible with many of our existing accessories, including cinema lenses, projector pedestals, and, most importantly, standard laser devices across the RealLaser portfolio.

We also introduced washable filters to help reduce consumable waste and TCO (total cost of ownership). Using RGB pure laser projectors results in considerable carbon emission savings (outlined below). In fact, customers may qualify for subsidies or credits from local, regional, or federal governments that support the switch to greener energy.

Christie CineLife+ RealLaser projectors: Annual energy savings and avoided CO_2 emissions

Projector	Annual savings vs Xenon (kWh)	CO2 emissions avoided (Imperial tons)
CP4455-RGB	36,949	28.9
CP4445-RGB	27,237	21.3
CP4435-RGB	23,305	18.2
CP4425-RGB	17,958	14.0
CP4420-RGB	10,749	8.4
CP4415-RGB	9,618	7.5
CP2420-RGB	10,786	8.4
CP2415-RGB	7,373	5.8

Annual CO_2 emissions saved by switching to RealLaser

LOWEST CO_2 EMISSIONS IN THE WORLD

Annual CO_2 emissions saved by switching to Real|Laser™

CP4455-RGB: 28.9 tons - 5.6 cars (equivalent)

CP4435-RGB: 18.2 tons - 3.6 cars (equivalent)

CP4420-RGB: 8.4 tons - 1.6 cars (equivalent)

Annual Savings and CO_2 Emissions Avoided Assumptions: 10hrs of operation per day, 365 days/year, xenon power consumption linear interpolation where necessary.
CO_2 calculations from EPA.GOV here: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

In conclusion

Christie RealLaser projection systems use environmentally friendly solid-state laser devices that save 300% in electricity consumption and CO_2 emissions compared to traditional lamp-based projectors – and offer efficiency that's more than 1,000% better than the technology used only 40 years ago. RealLaser projectors offer additional environmental impact by operating more efficiently, which generates less heat (BTUs) that requires extraction. Customers can also use environmentally friendly washable filters that generate less waste.

Christie CineLife+ RealLaser projectors achieve substantial efficiency improvements over not only the traditional projection systems but also the competition. With our second generation LOS (LOSv2) in our CineLife+ Series 4 projectors, Christie has further improved on all features – making RealLaser the best choice for customers who value efficiency, serviceability, and environmental responsibility. With our new upgrade kits, early adopters of the first RGB pure laser systems can continue with Christie's support or choose to upgrade to the latest version – and secure the most effective cost of operation and business investment.

Discover more

LOS lifetime whitepaper
The laser optical system, or LOS, is the heart of Christie® Real|Laser™ projectors. Learn how its lifespan is extended

Visit lamptolaser.com
Discover the factual and actual benefits, drawbacks, and properties of each cinema projection illumination source

Corporate offices

Christie Digital Systems USA, Inc.
Cypress
PH: +1 714-236-8610

Christie Digital Systems Canada Inc.
Kitchener
PH: +1 519-744-8005

Worldwide offices

Australia
PH: +61 (0) 7 3624 4888

Brazil
PH: +55 11 3181-2952

China (Beijing)
PH: +86 10 6561 0240

China (Shanghai)
PH: +86 21 6030 0500

China (Shenzhen)
PH: + 86 755 3680 7000

Colombia
PH: +57 (315) 652-9620

Germany
PH: +49 221 99 512-0

India
PH: +91 (080) 6708 9999

Mexico
PH: +52 (55) 4744-1791

Singapore
PH: +65 6877 8737

South Korea
PH: +82 2 702 1601

Spain
PH: +34 (0) 91 633 99 90

United Arab Emirates
PH: +971 (0) 4 503 6800

United Kingdom
PH: +44 (0) 118 977 8000

United States (Arizona)
PH: +1 602-943-5700

United States (Texas)
PH: +1 469-757-4420

For the most current specification information, please visit christiedigital.com

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