UV LED Systems Are Not Created Equal

Which factors are critical for ensuring optimal UV LED curing of Inks, Coatings and Adhesives?

A Phoseon Technology White Paper

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Overview

When evaluating features for UV LED curing systems, it's often unclear which of the many metrics and benchmarks are the most important selection criteria. Which are the most critical for ensuring optimal UV curing of inks, coatings and adhesives?

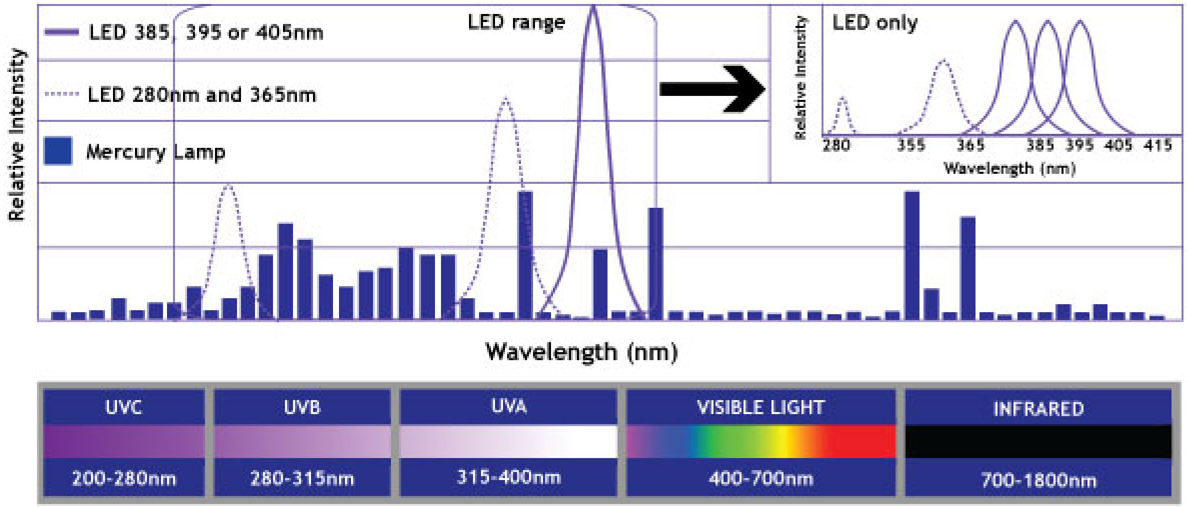
Two fundamental parameters to focus on are **peak irradiance** (measured in watts per square centimeter) and **energy density** (measured in Joules per square centimeter). But that's not it.

What is an LED?

LEDs are a solid-state device created from semiconductor material. On the surface, light emitting diodes (LEDs) may look the same. That visual similarity doesn't mean they all perform the same. They don't.

LEDs are a silicon technology. Because silicon is not an inherently perfect technology, no two LEDs are the same. As with silicon chips, a manufacturer can produce 1,000 LEDs and all will perform differently – some to a small degree and others more significantly. From LED to LED the variation can range from the wavelength of the light they produce to the power they emit (watts).

LED UV lights emit a narrow spectral output centered on a specific wavelength, +/- 10nm. This near-monochromatic distribution (see chart) requires tailored chemical formulations to ensure proper curing of inks, coatings, and adhesives.

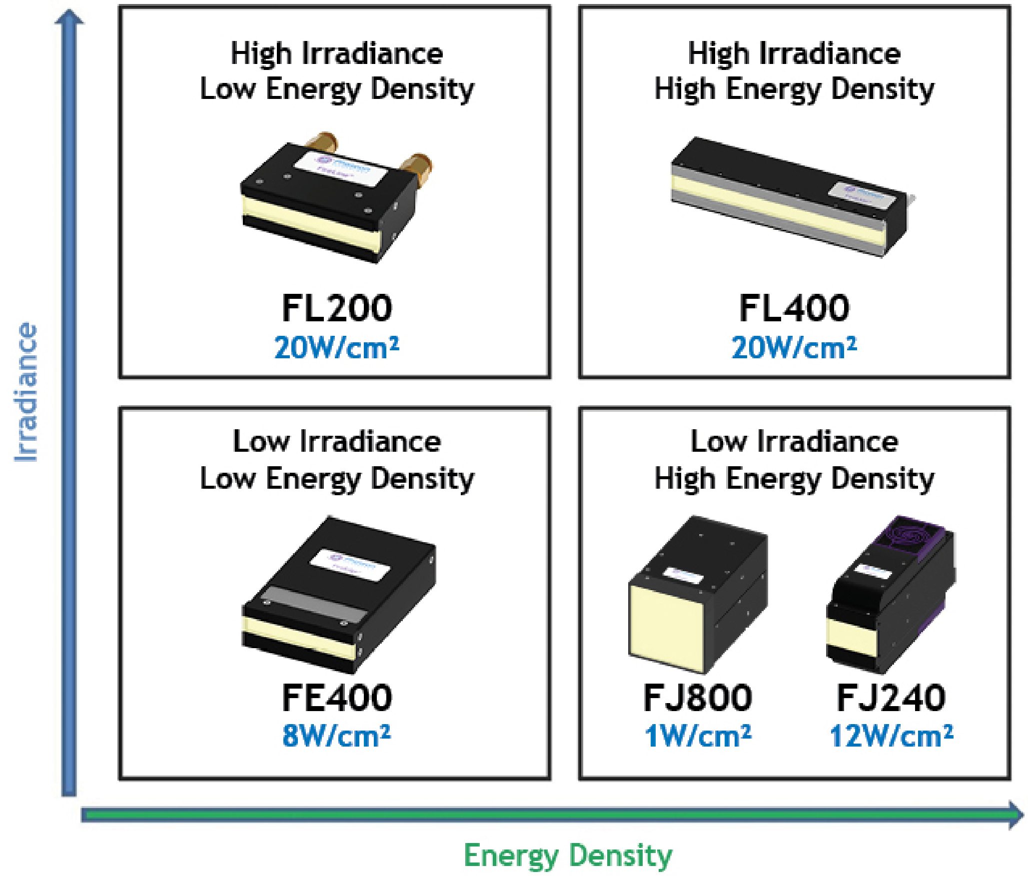


Having high-quality and consistent LED performance is critical. The lamp curing system plays a critical role in ensuring these key deliverables.

However, as outlined earlier, performance varies from LED to LED. If electrical current is applied to several different LEDs, each LED will produce a different level of power. The higher the electrical current needed to reach a certain power level, the faster the LED will degrade, thus shortening its lifetime.

By using raw LEDs, Phoseon can select LEDs with similar performance levels that need the least amount of current to produce the desired power level. This ensures uniform, consistent performance and long life expectancy across an array of LEDs.

Phoseon Technology has developed a large portfolio of products with varying maximum peak irradiance levels and energy densities to fit most curing needs. Phoseon matches the correct UV curing source to the needs of the application.



Raw LEDs vs. Packaged LEDs

An increasing number of manufactures are embracing UV LED due to its numerous benefits, including the ability to generate higher yields, reduced scrap, lower running and maintenance costs, and precision control. Furthermore, the UV output from high quality LED curing systems remains consistent over the life of the device and provides a more uniform result than arc and microwave lamps. That means tighter process control, less downtime, greater plant utilization and an overall better and more consistent product.

By purchasing “raw” LEDS from the manufacturer, which sorts the LEDs and put them in bins based on performance, Phoseon can chose the size and performance level of LEDs it wants, carefully selecting LEDS with similar characteristics. While no two LEDs are the same, Phoseon chooses LEDs that are most optimal – require the least amount of energy to get the most power and longest life -- with the least amount of performance variance.

While other UV LED lamp manufacturers use pre-assembled UV LED packages, Phoseon, which is 100 percent focused on curing with UV LED technology, designs its own arrays. With packaged LEDs, there is no way to know the quality of the LEDs or how much variance exists between them.

LEDs are not operated alone; they need to be mounted on a substrate, and arranged in a grouping or cluster called an array. The number and type of LEDs chosen, the arrangement of the array, the method of electrically connecting the LEDs, and LED cooling technology have significant impact on the performance of the system. All these factors make up Phoseon patented Semiconductor Light Matrix (SLM™) technology. Using raw LEDs allows Phoseon to design its SLMs to ensure optimal performance and reliability.

Depending on the type of curing system, Phoseon then mounts the SLM array on an air- or liquid-cooled heat sink, which pulls heat away from the substrate. Ensuring its substrate material is flat and tightly adhered to the heat sink ensures quick, even heat dissipation and the highest power output. Phoseon's UV LED curing systems emit peak irradiance up to 25 Watts/cm2 for air-cooled heads and 30 Watts/cm2 for liquid-cooled heads.

That may seem like Phoseon goes to great lengths to design and produce an UV LED curing technology. It does. Phoseon builds complete light engines, within its ISO 2015 facility, from individual diodes rather than using prepackaged LEDs. This allows it to match individual LED characteristics with other components to maximize the total UV energy.

The results are worth the effort: UV LED curing products with more consistency, longer useful life and more accuracy than any other products on the market. Phoseon backs this up with the best warranty in the market.

Peak Irradiance vs. Energy Density

Peak irradiance, also called intensity, is the radiant power arriving at the surface area and is instrumental in penetrating and curing the ink or coating. Peak irradiance can be affected by the output of the UV LED light source, the use of reflectors or optics to concentrate or contain the rays in a tighter surface impact area, and the distance of the source from the cure surface.

The second key parameter is energy density, also called dose or radiant energy density. Energy density is the measure of energy arriving at a surface per-unit-area during a defined period (called the dwell time or exposure time). A sufficient amount of energy density is necessary for full cure. Energy density is a factor of irradiance and exposure time and is managed by varying the speed or time that the substrate is under the UV LED lamp and the intensity of the light source.

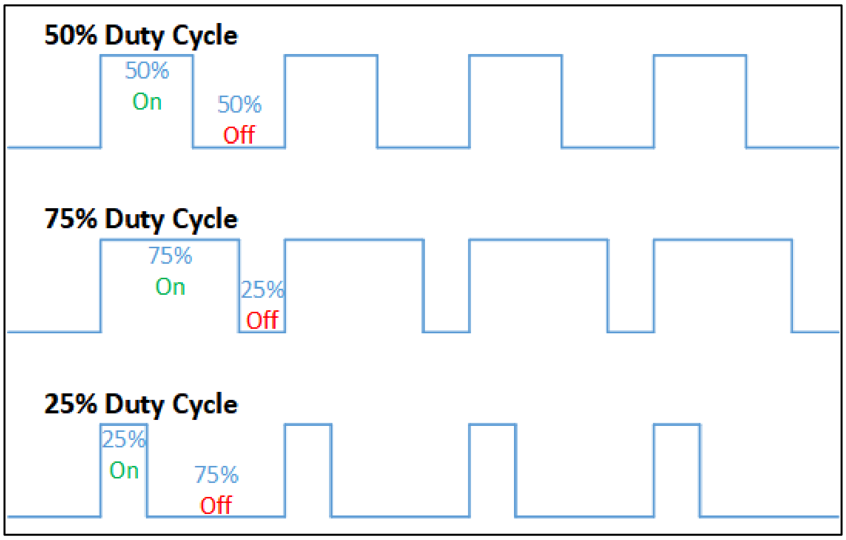
In terms of optimal UV LED curing results, which is more important, peak irradiance or energy density? The answer is that both are required. A minimum threshold of irradiance is needed to start the polymerization process, and then a dwell time of dose is needed to finish the curing process.

Some manufacturers describe their UV LED lamps as having the “highest irradiance” as if that feature alone is paramount for optimal UV LED curing. Let’s look more closely at how unusually high levels of UV irradiance are achieved and evaluate whether these high levels actually play a useful role in successful curing.

How PWM impacts Peak Irradiance

Pulse width modulation (PWM) techniques can be used to induce higher intensities of UV light from LED lamps. However, these higher UV irradiance levels using PWM can come with tradeoffs in energy density and product life.

PWM is a method of adjusting the level of power delivered from an electrical signal by effectively dividing the current flow into a series of discrete elements. In other words, PWM creates an on-off, on-off pattern that simulates voltages between full on and full off by changing the portion of the time the signal spends "on" versus the time that the signal spends "off."



Figur 1. Pulse Width Modulation techniques break electrical current into a series of on-off sequences (Courtesy of Thewrightstuff, Wikipedia)

When PWM is employed in a LED lighting system, the power to the light source turns on and off at a very fast rate, usually so quickly that the human eye can't register the intervals.

> *"Without sufficient UV dose the curing will be incomplete or flowed, leading to suboptimal results, lower yields, and increased scrap."*

This is one method used for “dimming” LED household lights: As the duty cycle grows shorter, the LED light seems to dim. In fact, the LED is emitting less light during any time period because the lamp is off more than it is on.

PWM is used in UV LED curing solutions to effect two principal outcomes. PWM can be used as a method of cooling the UV LED array, as the on-off switching of the lamps decreases the overall heat generated by the lamps, as for some fractional part of the time, the lamps will be off.

PWM can also be used for boosting light intensities of LED lamps beyond rated levels. As noted above, a key metric for evaluating the performance of a UV LED curing solution is the system’s peak irradiance levels. However, higher irradiance is reached by increasing power levels to the LEDs, which also increases the heat generated by the lamps and reduces the useful life of the LED diode.

In addition, PWM lowers energy dose. To achieve optimal UV curing, the coated surface must receive a sufficient dose of UV energy. However, if the light source for the UV dose is intermittently off and not delivering UV energy, the surface may not absorb enough UV density for curing despite elevated irradiance levels. Without sufficient UV dose, the curing will be incomplete or flawed, leading to suboptimal results, lower yields and increased scrap.

UV LED lamps are commonly used for curing inks in flexographic printing processes, because the UV LEDs are very efficient at drying inks while running presses at high speeds. If printed media passes below a PWM-based lamp during one of the intervals when the lamp is off, the media will roll off the presses with uncured areas in its surface.

Dose versus Irradiance

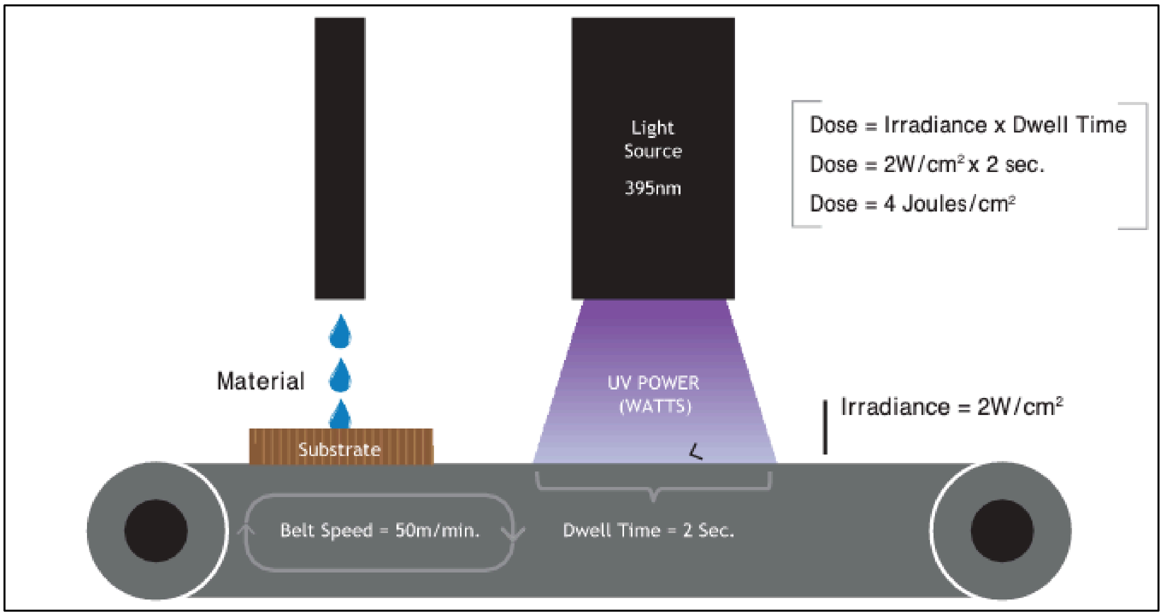


Figure 2. On fast-moving presses, the UV dose needed for full UV curing must be delivered in fractions of seconds; to attain a full cure with PWM-based lamps would require reducing belt speeds, and therefore throughput

Product Lifetime

Two major factors that affect the lifetime of LEDs are temperature and current with PWM. As LEDs convert electricity into light, heat is created within the p-n junction, known as the junction temperature. For an LED diode to achieve maximum life expectancy, the junction temperature has to remain in a safe operating zone.

That's how pushing LEDs to attain higher peak irradiance results can also impact the LED's life expectancy, because subjecting the LED to operating conditions outside of its specifications can lead to premature LED failure. Some lamp suppliers achieve their stated high-output irradiance by over-charging their diodes. Although this may increase the light output for a short amount of time, prolonged use at this level of irradiance will shorten the LED's lifetime, even with efficient cooling. Unfortunately for the customer, this failure will only show up after they have purchased the inferior product and then experience curing issues.

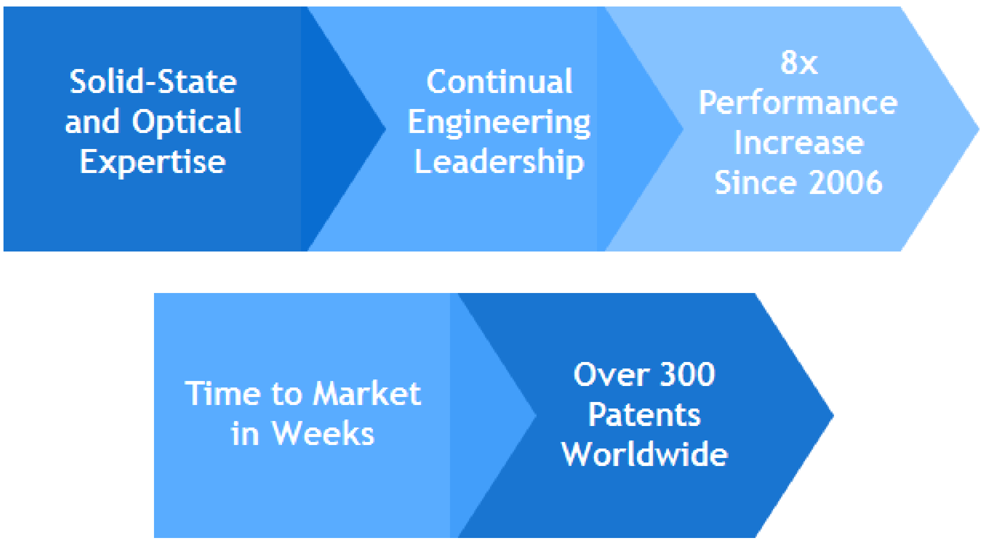
The Phoseon Advantage

When using UV LED light energy to cure inks, coatings and adhesives on everything from paper to furniture, or to provide deep-UV irradiance for disinfection and decontamination in medical applications, having high-quality and consistent LED performance is critical. As the world leader in UV LED industrial curing, Phoseon delivers rugged, high-performance products for many application specific solutions.

Phoseon UV LED curing solutions are designed to deliver reliable, linear power at a steady-state of UV output without using PWM techniques that push lamps to attain unsustainably high levels of irradiance. Steady-current Phoseon UV LEDs deliver consistent but highly controllable levels of UV light that provide optimal energy to drive the appropriate UV LED curing performance for a diverse range of applications. Phoseon uses patented thermal management techniques, including air- or liquid-cooled heat sinks, to remove excess heat from the system while providing a consistent operating temperature for the diodes to function at maximum performance over their operating lifetime.

Reliability Engineering is at the core of the company. With over 300 patents and trademarks worldwide, Phoseon has earned the reputation for innovation, quality and reliability. Our customers benefit from a thorough and proven product development cycle including advanced analysis such as highly accelerated life testing (HALT) to provide process consistency in harsh and unstable operating environments. In addition, we have been performing actual life testing with light sources for many years. Our longest lasting lamp to-date reached over 70,000 hours (8 years!) of constant on time.

Phoseon assembles its market-leading systems in a semiconductor-based clean-room environment. Manufacturing engineers are intimately involved with the product design starting with new product development, through initial production, and then into sustaining. Phoseon also utilizes advanced automation, burn-in, and statistical quality control (SQC) throughout its manufacturing process. Additional focus is applied to supply-chain quality, capacity, and redundancy for continuous product flow.



With all these variables, finding the right UV LED curing technology to produce the proper peak irradiance and energy density for your specific curing application may seem complicated. But Phoseon has decades of experience matching the correct UV curing solution to the needs of the application. Phoseon has developed the largest portfolio of products with varying maximum peak irradiance levels and energy densities to fit the most exacting curing needs.

Author

Joe Becker, Product Marketing Engineer, Phoseon Technologies

For more information about Phoseon Technology products and services, please contact:
Joe Becker, joe.becker@phoseon.com

About Phoseon Technology

The world leader since 2002, Phoseon Technology pioneered the use of LED technology for Life Science and Industrial Curing applications. Phoseon delivers innovative, highly engineered, patented LED solutions. The company is focused 100% on LED technology and provides worldwide support.

Contacts

For more information about Phoseon Technology suite of products, visit **http://www.phoseon.com/** or call **(503) 439-6446**