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# Laser Light Source
## Delivers Superior Optical Control

Laser diode-pumped phosphor light source offers higher luminance and scalable efficiency suitable for architectural and vehicle lighting, and projection displays.

BY JULIAN CAREY & PAUL RUDY
SORAALASER

Legacy light sources such as halogen and metal halide produce highly collimated directional beams, but with short life and lower efficiency than LED sources. LEDs are highly efficient and long lasting, but are poor at creating beam angles below 10 degrees with small optics.

This is fundamentally possible because laser diodes (LDs) do not suffer efficacy droop in the way that LEDs do. InGaN laser diodes based on semi-polar orientations of GaN operate at 3 to 5× higher gain compared to more conventional c-plane InGaN LDs.

Laser diode-pumped phosphor light sources utilize a high-power blue InGaN laser diode to excite a very small phosphor target — about 300 microns in diameter. The phosphor converts the laser light to broad-spectrum, incoherent white light, eliminating laser eye-safety risk. The small phosphor spot size allows for greater optical control of the down-converted white light emission. As a result, extremely narrow beam angles can be created, as small as 2 degrees with 1-in.-diameter optics. The resulting sources are the smallest and most intense solid-state light sources commercialized for lighting applications, with luminance that is up to 10× that of the brightest LEDs.

This ultrahigh luminance then enables high-efficiency waveguide delivery, sharp patterns with high contrast from small optics and spatially dynamic light projection.

Specialty lighting applications that make use of very tight beam angles include entertainment and architectural lighting and are some of the most established users of halogen and high-intensity discharge (HID) light sources. Outdoor applications including street lighting and stadium lighting utilize very high-luminance sources like HID in order to optically control the light to achieve a complex illuminance pattern on the roadway or stadium grounds while maintaining a manageably small luminaire size. Specialty lighting applications like vehicle forward lighting and projection displays aim to achieve long illuminance throw, precise beam shaping and spatial beam modulation, and have historically applied HID technology to a great extent. LEDs have been adopted by all of these applications to some degree, and offer their well-known benefits of small form factor, reliability and luminous efficacy, but are not able to be utilized in high-luminance applications.

However, after significant development time, both HID and LEDs are limited from the standpoint of luminance. Development of Xenon HID light sources for automotive and entertainment lighting applications



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Germany & Other Countries
Laser Components GmbH
Tel: +49 8142 2864 – 0
Fax: +49 8142 2864 – 11
info@lasercomponents.com
www.lasercomponents.com

France
Laser Components S.A.S.
Tel: +33 1 39 59 52 25
Fax: +33 1 39 59 53 50
info@lasercomponents.fr
www.lasercomponents.fr

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk

Nordic Countries
Laser Components Nordic AB
Tel: +46 31 703 71 73
Fax: +46 31 703 71 01
info@lasercomponents.se
www.lasercomponents.se

USA
Laser Components USA, Inc.
Tel: +1 603 821 – 7040
Fax: +1 603 821 – 7041
info@laser-components.com
www.laser-components.com

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have reached luminance values of 1.5 × 108 cd/m$^2$, or for reference, approximately 1000 lumens from an arc size of a couple of millimeters in diameter, although the overall size of HID lighting systems is much larger[1]. Despite their luminous efficacy, LEDs offer luminance somewhat less than the HID example above, because efficiency droop with increasing drive power also presents a fundamental challenge for LEDs to achieve higher luminance. As a new solid-state, high-luminance light source, laser light technology has now demonstrated luminance higher than 1.0 × 109 cd/m$^2$, or more than six times the highest HID.

**Technology fundamentals**

By fabricating a blue laser diode from semi-polar orientation Gallium Nitride (GaN), blue laser light is produced at higher levels of power due to the high gain in the device. As important, laser diodes show minimal droop characteristics, meaning that, for the first time, high-power lasers of very small scale are being implemented in specialty lighting applications. Unlike a blue LED that emits a few watts of diffuse optical energy per square millimeter, the watts of light produced from the laser diode emanate from a light-emitting area only microns in width, and can therefore illuminate a tiny spot that is hundreds of microns in diameter.

To complete the spectrum, the blue radiation is partially converted to longer wavelengths by a phosphor element. Innovations in high-temperature phosphors and binding materials have enabled phosphors to convert light efficiently at the elevated power densities and temperatures that result from the laser light architecture.

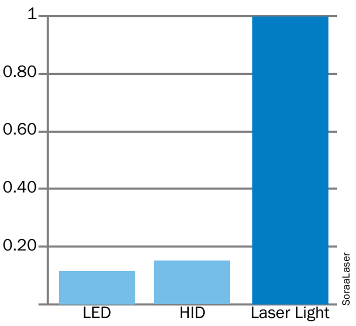
Two implementations of laser light have been developed that both achieve high luminance. The first implementation is composed of a blue laser module that uses a fiber optic of arbitrary length to transport the blue light to the end where the light illuminates the phosphor element. Typical optical fiber carrying laser radiation operates at a transport efficiency of 99.8 percent per meter, thus losses are very small even for significant fiber lengths. With this arrangement, the white-light-emitting element may be sealed in a location remote from the laser and its electronics, which may be placed in another location that has more favorable physical and thermal characteristics.

In the second implementation, the phosphor element is placed in close proximity to the laser diodes, resulting in a fully integrated surface mount device of 7-mm$^2$ dimensions. In contrast to other solid-state light sources, the phosphor is operated as a reflecting element. This placement offers the advantage of straightforward heat sinking of the phosphor element, which is important due to the high levels of power density. Reflectance from the phosphor also enables the configuration of safeguards on the emission of blue collimated laser light. Reflected light can be blocked by beam blocks or observed by sensors, both of which can ensure that blue collimated laser light is never released. In each of the two configurations, up to 500 lumens are emitted from a light-emitting area only 300 microns in diameter, resulting in luminance levels in excess of 1000 Mcd/m$^2$.

Efficacy of the light output also remains roughly constant as power is driven higher due to the low-efficiency drop of the lasers with increasing power.

**Narrow beam angles**

High luminance at the laser light source provides valuable optical system advantages including a narrow beam angle, sharp beam cut-off and smaller optical systems. Enabling beam angles smaller than 8 to 10 degrees from 25- to 50-mm optic diameter has been challenging with conventional light sources. Utilizing laser light sources, beam angles of 2 degrees or lower have been demonstrated with total internal reflection optics of less than 30 mm in diameter, well within convenient lighting system form factor. For existing optical systems that seek to maintain the same beam angle, the optics used may be designed to be smaller, lighter and have sharper beam geometries. Since laser light approximates a point source, the optical characteristics lend themselves particularly well to diffractive-type optical elements for beam sizing and shaping. For example, a light-shaping diffuser element can transform the output beam of a 1-degree spotlight module to a rectangle of 1 degree by 10 degrees with efficiency higher than 92 percent. Moreover, liquid crystal (LC) lens technology can be added downstream from laser light modules in order to electronically control and dynamically change the beam angle and/or shape.




Relative luminance from three sources.
HID: high-intensity discharge.


A surface-mount device laser light component.


A separable laser module and phosphor element linked by fiber optic.





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Laser Components GmbH
Tel: +49 8142 2864 – 0
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France
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Tel: +33 1 39 59 52 25
Fax: +33 1 39 59 53 50
info@lasercomponents.fr
www.lasercomponents.fr

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Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
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Nordic Countries
Laser Components Nordic AB
Tel: +46 31 703 71 73
Fax: +46 31 703 71 01
info@lasercomponents.se
www.lasercomponents.se

USA
Laser Components USA, Inc.
Tel: +1 603 821 – 7040
Fax: +1 603 821 – 7041
info@laser-components.com
www.laser-components.com

■ High-Luminescent Laser Diode

**Vehicles, projection displays**

Vehicles have been introduced with laser light for the high beam extender function and have achieved several times the throw distance previously achieved. With laser light, illuminance sufficient for visibility (several lux) is thrown out to as far as 1000 meters. Driving safety is increased as greater braking distances at nighttime are enabled at high speeds.

Projection display applications implementing laser light are well established where laser light is modulated spatially with very high resolution, usually with a micromirror array. The first implementations of a laser and a spinning phosphor wheel as a lighting system for projectors date from 2010. As this architecture has further developed, it is becoming more solid-state and no longer using a rotating wheel, thus transitioning to more applications where very highly intelligent lighting control is desirable.

From the standpoint of creating a matrix field of controllable light, LEDs have demonstrated efficacy at a relatively coarse level in automotive lighting applications. For example, these applications help to reduce glare for other drivers by using sensors and selectively dimming part of the projected light field. With an approximate point source like laser light, high-precision and high-definition refinement of spatial light control is enabled, without the need for large arrays of LEDs. By combining laser light and a liquid crystal or micromirror device in a small form-factor, efficient package, automotive and specialty lighting applications may benefit.

Society of Light & Lighting

A streetlight demo with blue laser light transported by fiber to the phosphor element at top with optic.

SoraaLaser, Lens Vector

Dynamic control of beam angle with liquid crystal lens operated by a touchpad.

With small form-factor laser light sources like surface-mount device emitters, architectural, entertainment and venue lighting similarly can harness a higher luminance than that available from HID in order to generate long-range illumination or generate distinctive high-contrast short throw illumination effects. Spots can be combined with other lensing and diffusing effects to control the beam angle and shape dynamically. Alternatively, fixed installations can use efficient micro-featured diffusers to offer specially shaped beam geometries.

Efficient transport of the blue laser light through a fiber optic enables designs where the white light source is almost purely optical in output and separable from the laser module and drive electronics. For example, streetlights and stadium lights are an application area where this configuration offers a benefit, reducing service needs at the light head at the top of the pole. The phosphor-converting element could be permanently sealed in a lighter, smaller optical structure less subject to wind and costly service visits on a mobile lift. The laser module and electronic assemblies are positioned in the pole, base or underground.

**Future directions for laser light**

Laser light is in the early days of its implementations in specialty lighting, and performance gains are rapid. Efforts are underway to further increase luminance by driving the spot size smaller for a given lumen reference. As LEDs accomplished throughout their history, laser diodes' luminous efficacy will continue to improve from the approximately 40 to 50 lm/W level of today to 100 lm/W and beyond. Most importantly, as laser light converges with LED technology in efficacy, it will have the additional advantage of not suffering drooping efficacy with increasing power. This stability will help keep emitter populations lower and fixtures smaller, as there will not be significant efficacy vs. power trade-offs for individual devices.

Development is also underway on applications that scale to higher levels of lumen output per source. Current imple-



Germany & Other Countries
Laser Components GmbH
Tel: +49 8142 2864 – 0
Fax: +49 8142 2864 – 11
info@lasercomponents.com
www.lasercomponents.com

France
Laser Components S.A.S.
Tel: +33 1 39 59 52 25
Fax: +33 1 39 59 53 50
info@lasercomponents.fr
www.lasercomponents.fr

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk

Nordic Countries
Laser Components Nordic AB
Tel: +46 31 703 71 73
Fax: +46 31 703 71 01
info@lasercomponents.se
www.lasercomponents.se

USA
Laser Components USA, Inc.
Tel: +1 603 821 – 7040
Fax: +1 603 821 – 7041
info@laser-components.com
www.laser-components.com

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mentations emit up to 500 lumens, and applications like venue and stadium lighting would benefit — from a system design standpoint — from individual lighting elements of several thousand lumens. Laser diodes lend themselves particularly well to being combined into a single beam, so as long as the phosphor element is properly matched, overall lumen output per source is expected to rise with new designs.

Correlated color temperature (CCT) and color rendering index (CRI) for recent laser light applications are around 5700 K and 70 CRI respectively, which lends laser light today to outdoor and specialty applications. Future work in phosphors and laser diode engineering will enable a more complete spectrum and allow warmer, higher CRI light for indoor applications.

Breakthroughs in semi-polar GaN materials have led to reliable, high-power blue laser diodes. These lasers, combined with high-power-density phosphor components, have enabled laser light to take its place as a new platform in solid-state lighting. Laser light technology delivers the highest luminance available of any light source, and enables narrower beam angles and longer throw for directional lighting applications of many types, including vehicle lighting and projection display. The success in these high-intensity lighting applications positions the technology to make great contribution to intelligent general lighting by offering higher luminance, more scalable efficacy and the capability to work with complementary technologies in a nearly ideal way to control light spatially.

**Meet the authors**

Julian Carey is the product and technical marketing manager at SoraaLaser. He oversees product strategy and marketing for laser-based light sources; email: jcarey@soraalaser.com.

Paul Rudy is a co-founder and senior vice president of SoraaLaser. He has worked in the field of lasers and photonics for 20 years; email: prudy@soraalaser.com.

**References**

1. T.Q. Khanh (2015). *11th International Symposium on Automotive Lighting – ISAL 2015 – Proceedings of the Conference: Volume 16.* Munich: Utz Verlag Gmbh.