Proposal for Standards for Point Source and Surface Source Light

By Mark Baker

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Overview

In April 2022, Cree Lighting published a white paper that recognized, for the first time in the LED lighting industry, that LEDs emit non-uniform luminance.[1] Cree noted that there are no metrics for this spatially non-uniform luminance and called on the LED lighting industry to develop such metrics and standards. This paper outlines steps that can be taken to meet Cree's challenge.

Cree Lighting White Paper

The Cree Lighting white paper is a plea for the LED lighting industry to publicly recognize that LED light has not been measured correctly. The following two quotes highlight the seriousness of this situation.

"*Not one of the existing metrics takes into account the non-uniform emitting surface of a LED luminaire*"

"*Without a speedy agreement on metrics for measuring LED intensity, spectrum, photometry and LED spacing, we will be installing millions of LED luminaires for street lighting purposes that are not suitable for use, could even be described as dangerous, and that will be costly to replace.*"

Non-Uniform Spatial Energy

The utility company Evergy shows an example of the non-uniform energy of LED light on the Evergy website.[2] The diagram highlights the non-uniform luminance of an LED light source, with the peak intensity shown in white in the center and the lower intensity shown in cyan on the outer edges.

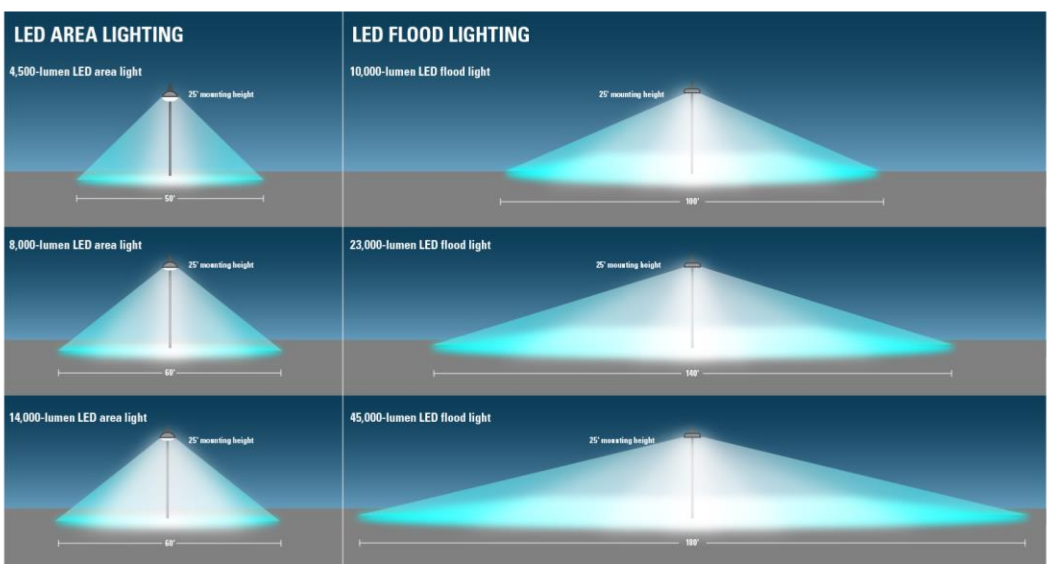

Figure 1 - Non-uniform LED Light

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[1] https://online.flippingbook.com/view/702884488/

[2] https://www.evergy.com/ways-to-save/resources-link/equipment/led-flood-and-area-lighting

Vocabulary

The first step to answering Cree Lighting's challenge is to standardize vocabulary. We propose the following two definitions.

Point Source: A source that emits essentially spatially isotropic light and which can be modeled as a mathematical point. Examples include the sun, a candle, tungsten filament, fluorescent and sodium. Brightness is measured with luminous intensity in candela.

Surface Source: A source that emits spatially anisotropic light from a non-curved flat surface and which can be modeled as a mathematical Lambertian. An example is a Light Emitting Diode. Brightness is measured with luminance in nits (candela per square meter).

Diagrams

Existing diagrams generally assume point source light. For example, Figure 2 from the IES RP-8-18 standard shows an incandescent lamp uniformly illuminating in all 4pi steradians in space, with the light eventually reflecting off a surface and onto the eye.

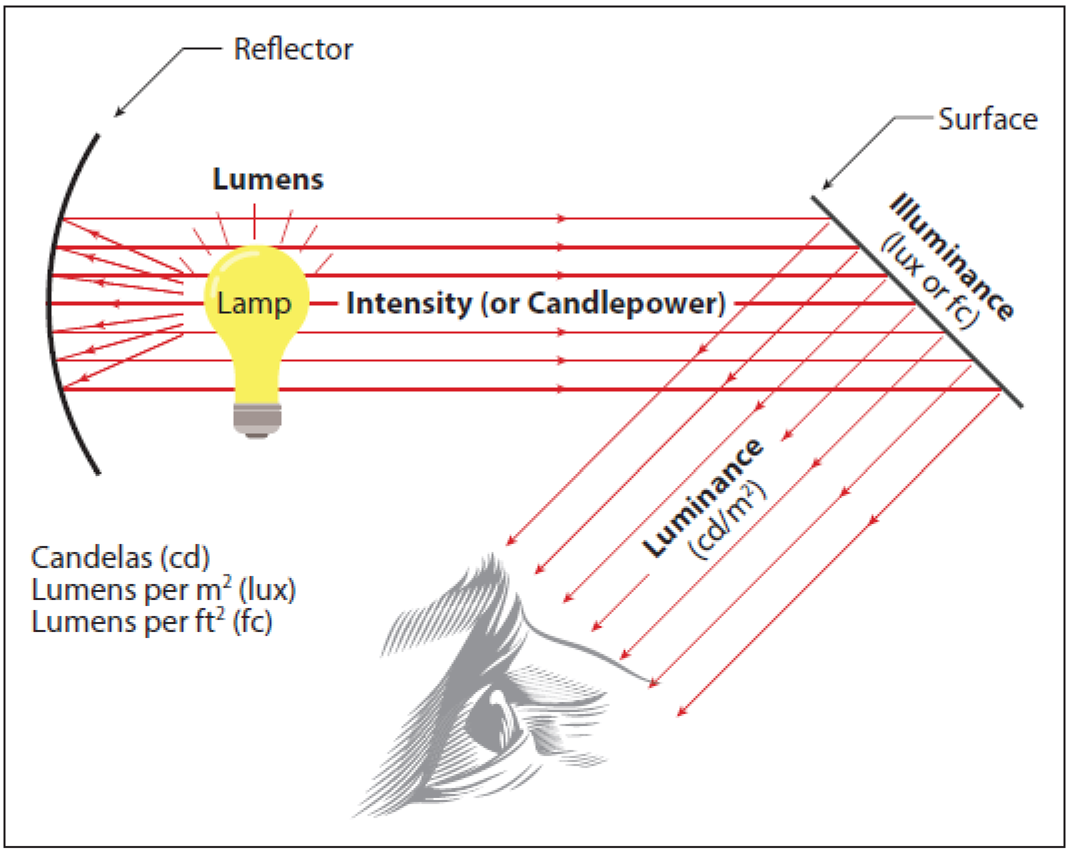

Figure 2-15. Relationship of basic lighting terms.

Figure 2 - IES Basic Lighting Terms

With surface source light, the non-curved flat surface generates non-uniform luminance, and therefore the diagram in Figure 2 is not applicable. Figure 3 is a valid diagram for surface source LED lighting. The flat chip generates a Lambertian spatial shape, such that each point in space has a different luminance value. The non-uniform luminance is transmitted nearly unchanged until it reaches the eye. The nerves then receive non-uniform energy and attempt to transmit this information to the brain for interpretation. As noted in the Cree Lighting white paper, none of the current metrics considers this non-uniform luminance.

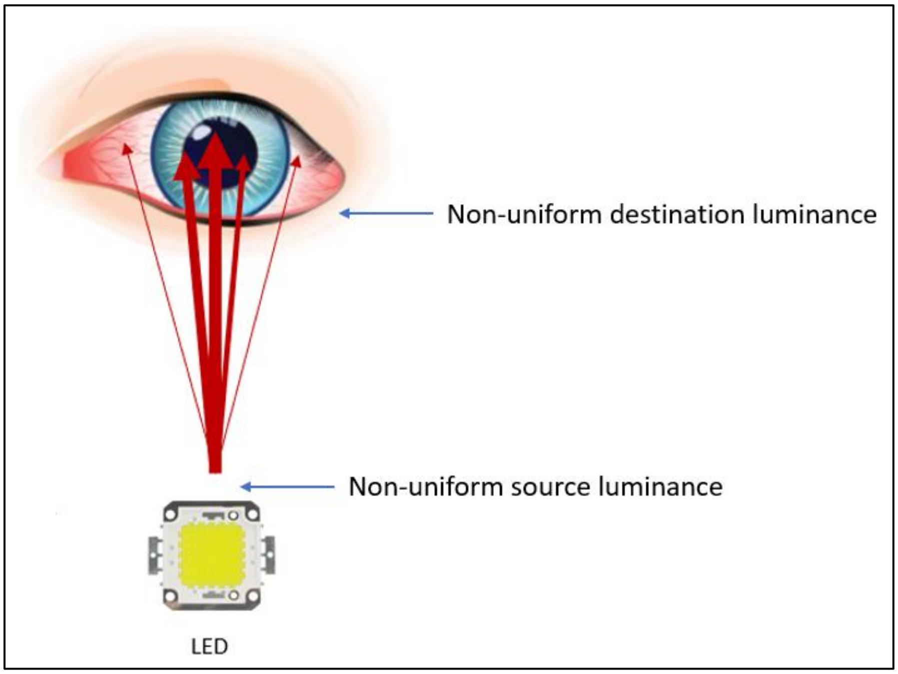

Figure 3 - Non-uniform Luminance

Energy Efficiency and Light Quality

The definition of **energy efficiency is providing the same quality of service using less energy**. There are currently no metrics for light quality, and the claim that LEDs are energy efficient is invalid. Metrics for light quality should be developed to allow comparison of light sources. Given that point sources and surfaces provide different services (uniform illumination versus non-uniform directed beam), an energy efficiency comparison cannot be made, and yet this invalid comparison has been done repeatedly by governments and the LED lighting industry. A standard for light quality would help solve that problem. Light qualities would include spatial uniformity (e.g., spatially uniform is high quality), spectral power distribution (e.g., high blue without corresponding high red would be considered low quality) and flicker.

Color Rendering

Color Rendering Index (CRI) is sometimes used as a quality metric, but the environmental surroundings and time of use have been ignored. While a high CRI may be useful for an indoor classroom at noon and could be considered to be high quality, a high CRI from an outdoor lamp at night is psychologically disturbing and would be considered to be low quality.

Metrics

Considering that the spatial energy emitted by an LED is non-uniform, the spectral and temporal values may also be non-uniform, and this needs to be addressed. At a minimum, standards for surface source lights must include the following:

Peak Luminance – This is the measure of the highest luminance value measured in near-field at the chip, and, unless otherwise stated, would be implied to be the luminance that reaches the eye since LED light has very little dispersion.

Peak Luminance Spectral Power Distribution – The Spectral Power Distribution can be different at each point in space, but a single SPD graph can be made for the one point in space that has the peak luminance.

Peak Luminance Flicker – The flicker can possibly be different at each point in space, but flicker metrics could be applied to the point that contains the peak luminance. The effects of flicker from spatially non-uniform light have likely not been correctly studied.

Precision

At this time, the author is unaware of any device that can precisely measure peak luminance, peak luminance spectral power distribution, or peak luminance flicker in far field. Therefore, these measurements must be made in near field, in a laboratory setting at 1 micrometer from the chip. The precision should be at the femtometer and femtodegree scales for surface source devices.

Measuring Devices

Handheld Measuring devices likely do not have the firmware or software to properly measure and display light properties from surface sources because they likely are treating the light as if it is uniform or averaging out the necessary precision. Any far field measuring devices must explicitly state its precision abilities related to surface light sources.

Human Health

The intensity of LED light is following Haitz's law and is now extremely intense. LED chip manufacturers exceeded 100,000,000 nits as of 2018 and continue to increase the intensity. There is no theoretical limit for the energy density from an LED light. While laser light has been regulated for decades, LED light is unregulated, and this is hazardous for human health.

Standards should be set for eye safety and neurological safety due to exposure to LED light. 300 nits are the approximate maximum comfort level and 50,000 nits is the maximum tolerance level for humans. These values may be lower for sensitive receptors. For flashing lights, a study funded by the Epilepsy Foundation found that a light exceeding 20 nits was likely to trigger seizures.[3] The non-uniform energy of LED light can trigger seizures, migraines, anxiety, panic attacks, distorted vision, and other

[3] https://onlinelibrary.wiley.com/doi/10.1111/epi.17175

negative neurological reactions. The industry must determine the safety limits for the peak luminance, spectral power distribution, and flicker for surface source light.

People who have light sensitivity disabilities or who simply have exquisite sensitivity are disproportionately harmed by LED light. Standards that protect this group of people need to be developed by the industry.

Ecosystem Health

The intensity of LED light causes it to have powerful effects even miles away from the source. LED light with blue content is alarmingly hazardous at night. For example, a 2019 study showed that blue wavelength light shortens the lifetime and cause brain neurodegeneration of drosophila.[4] The industry must develop metrics and standards for both point source and surface source artificial light that will keep cellular systems and the ecosystem safe.

Way Forward

Given the differences between a point source and a surface source of light, separate standards should be developed for each type of light source. For example, IES RP-8-18 Roadway and Parking Facility Lighting is currently being used for LED streetlights, which is leading to invalid results. The concern posed by Cree Lighting is that as LED lighting installations are being implemented incorrectly, the results may be hazardous and costly to fix. The IES RP-8-18 needs two separate versions: IES RP-8-18-Point for point source lighting and IES RP-8-18-Surface for surface source lighting.

About

Mark Baker is the founder and president of the Soft Lights Foundation, a non-profit advocacy group dedicated to protecting humans and the ecosystem from the harms of artificial light. Mr. Baker has a Bachelor of Science in Electrical Engineering from the University of California at Santa Barbara.

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[4] https://www.nature.com/articles/s41514-019-0038-6