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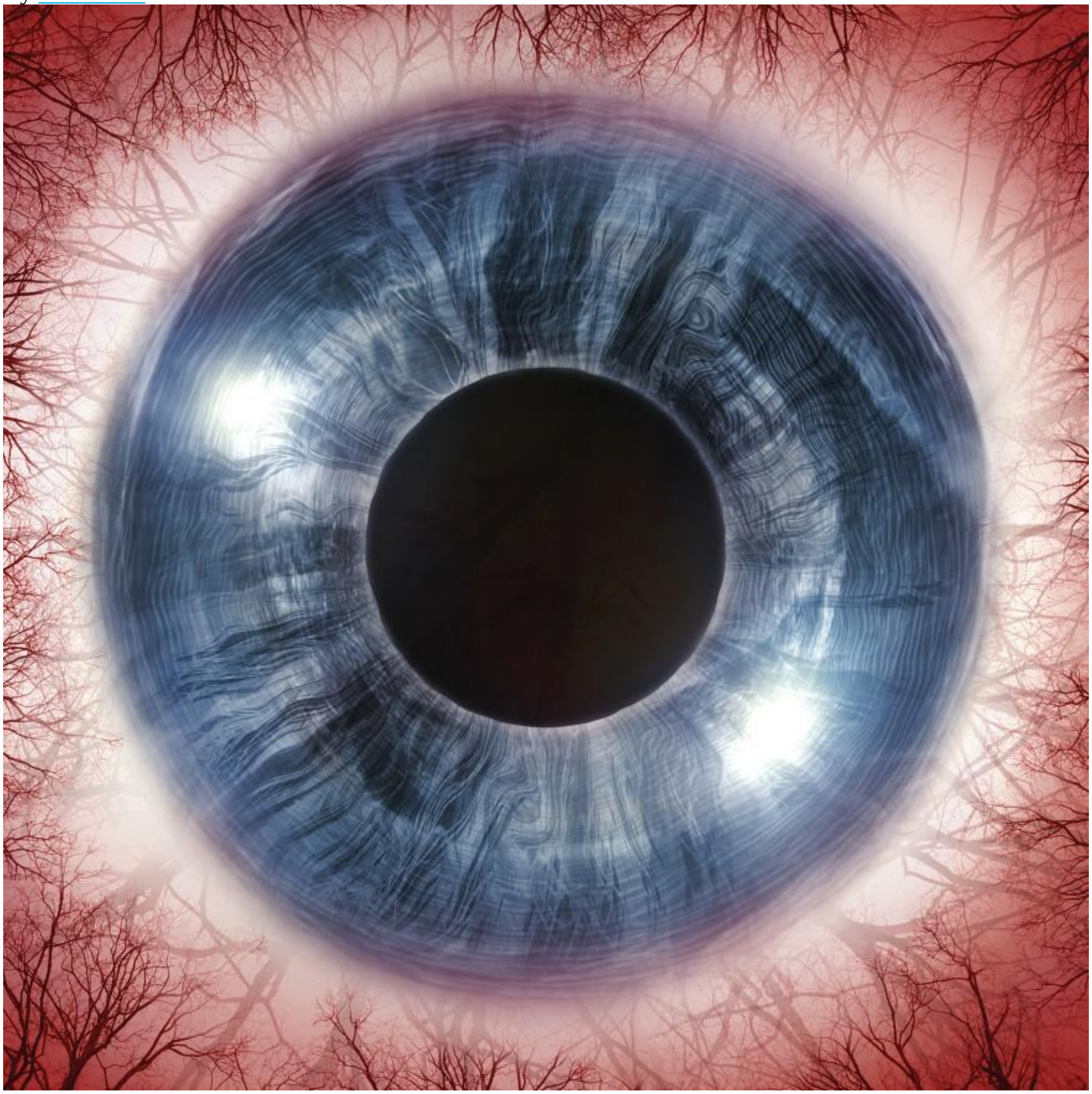
Blue-Light Hazard and LEDs: Fact or Fiction?

The advent of solid-state lighting in everyday applications has renewed research interest in whether its spectral profile can lead to increased health risks.

By Alice Liao



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Little is certain about the health implications of long-term exposure to LED lighting, but the proliferation of phosphor-coated white LEDs in everyday applications has sparked a renewed interest in research. Recent investigations have centered on the spike in the short-wavelength blue region of LEDs' spectral power distributions (SPDs). Studies in disciplines outside of lighting have linked exposure to everything from circadian disruption to blue-light hazard, the latter of which this article will focus on. But should the general population be alarmed? Not really, say the lighting experts.

The Hazards of Blue Light

Blue-light hazard was discovered in the field of occupational health and safety in the 1970s, predating the invention of white LEDs. The term describes the acute photochemical damage to the retina caused by "staring at an intense light source," such as a welding arc or the sun, says David Sliney, chairman of the IES Photobiology Committee. The radiation absorbed by the retina unleashes a series of chemical reactions that can lead to retinal inflammation, cell death, and white lesions within a day or two of exposure.

Research conducted over the last 40 years in medical academia has connected these phototoxic responses to short-wavelength radiation in the range of 400 to 500 nanometers—with a peak around 440 nanometers—prompting speculation about the safety of blue-rich light sources used in general illumination.

Fluorescent sources also faced scrutiny for the blue peak in their SPDs, but as John Bullough, director of the Transportation and Safety Lighting Programs at the Lighting Research Center (LRC) in Troy, N.Y., explained in the *Journal of the Illuminating Engineering Society* in 2000, their low luminance makes any potential for risk of blue-light hazard "negligible."

Photochemical damage from blue light exposure has also been implicated in age-related macular degeneration (AMD), a leading cause of vision loss in people over 65. Biomedical researchers suspect that long-term exposure to short-wavelength blue light can create oxidative stress on retinal cell structures, resulting in the accumulation of lipofuscin, a lipid-containing waste product that has been attributed to AMD.

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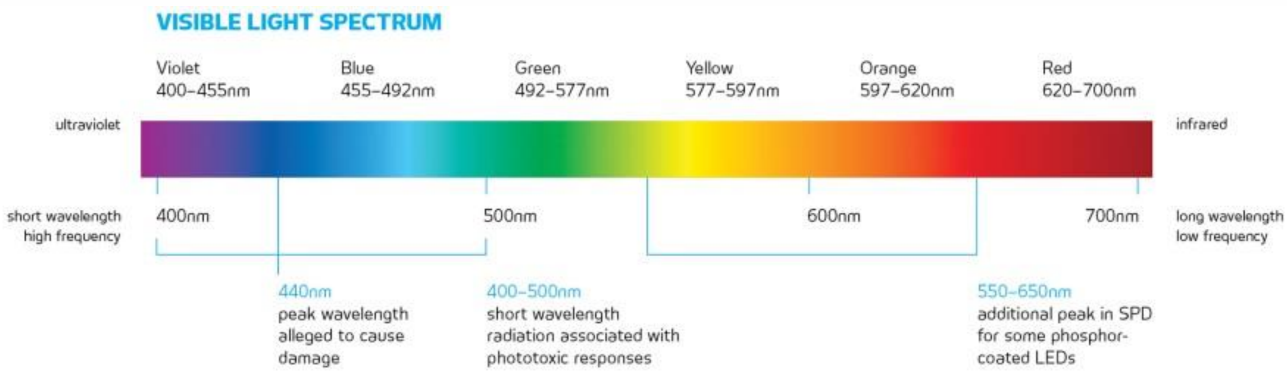

Why So Blue?

Typical white LEDs consist of gallium nitride (GaN) and blue dye and a phosphor coating that converts a portion of the blue light into white. These phosphor-coated white LEDs can be fabricated with customized spectral profiles, but the process necessitates a spike in blue radiant energy. The phosphors produce a second, broader, and, in some cases, higher peak between 550 and 650 nanometers.

LEDs with correlated color temperatures (CCTs) topping 3000K are often singled out for their high blue content. In June, for example, the American Medical Association released a report cautioning against the use of high-CCT LEDs in outdoor applications, citing health concerns such as melatonin suppression and circadian disruption—which are technically distinct from blue-light hazard. Although CCT does correlate with a source's blue-light content, the U.S. Department of Energy (DOE) states in its 2013 "Optical Safety of LEDs" fact sheet that the proportion of blue emissions in the spectrum "is not significantly higher for LEDs than it is for any other light source at the same CCT."

The brightness of LEDs has also raised concerns. As a point source, the diodes emit a concentrated directional light that can be unpleasant to view directly. Still, their output is less than what the DOE cites as a risk for blue-light hazard: a luminance exceeding 4 gigacandela per square meter, and an illuminance exceeding 400,000 lux. Moreover, in interior lighting applications, the sources are often diffused, mitigating any discomfort.

Studies in Blue

The 1976 *Nature* article “Retinal Sensitivity to Damage from Short Wavelength Light,” by William Ham Jr., Harold Mueller, and David Sliney continues to be the go-to reference in contemporary research on blue-light hazard and AMD. Undertaken to differentiate between thermal and photochemical injuries caused by short-wavelength light, the study established minimum thresholds for damage by irradiating the retinas of anesthetized monkeys with lasers at wavelengths between 442 nanometers and 1,064 nanometers. Exposure periods ranged from 1 second to 1,000 seconds.

In his literature review, Bullough notes that the researchers determined “light at 442 nanometers was 100 to 1,000 times more damaging than energy at 1,064 nanometers” and that the lesions produced by the former seemed chemically induced while those inflicted by the latter were burns. This and a subsequent study by Ham formed the basis for the safety guidelines by the International Commission on Non-Ionizing Radiation Protection on protection against laser radiation, as well as for *ANSI Z136.1-2007: American National Standard for Safe Use of Lasers*.

Similar laboratory experiments also observed photochemical retinal damage associated with intense short-wavelength radiation. In a 2011 literature review in *Photochemistry and Photobiology*, Dutch researchers Dirk van Norren and Theo G.M.F. Gorgels examined 56 such papers, the most recent of which were published in 2009 and 2010, involving the directing of light from multiple sources into the retinas of live monkeys, rats, rabbits, or squirrels for a period of time, ranging from one second to five hours.

Extrapolating lighting recommendations from research can be tricky. In the 2014 post “Blue Light Hazard … or Not?” on the blog All Things Lighting, Ian Ashdown, chief scientist for Lighting Analysts and president of Vancouver-based ByHeart Consultants, notes that the light intensities used in much of the research to date were often too high to be instructive in determining health risks from long-term exposure. While the studies demonstrate that “both ultraviolet and blue light can

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permanently damage the retina if focused onto a small spot," he says in an email to architectural lighting, "the exposure time necessary to do damage was equivalent to staring at the tropical noonday sun for 15 minutes without blinking."

The Problem with Pinpointing LEDs

Excessive light levels have plagued similar studies on LEDs. In "Photoprotective Effects of Blue Light Absorbing Filter Against LED Light Exposure on Human Retinal Pigment Epithelial Cells In Vitro," published in 2013 in the *Journal of Carcinogenesis & Mutagenesis*, the researchers subjected cultured, human retinal cells to intensities of 5mW per square centimeter of white, blue, green, and red LED light in three 12-hour on–off cycles, with and without a blue-light-absorbing filter. Although the filter did prevent phototoxicity from LED lighting, Ashdown says that the light exposure used on the cells was "hundreds of times more light than the human retina would be exposed to from LED light sources." Moreover, because the experiment was done with cultured cells, it did not factor in the ability of a human's "biological system" to repair cellular damage.

Even when researchers have attempted to approximate real-world applications of LEDs, a lack of lighting expertise has led to uncontrolled experimental conditions. In a 2014 paper in *Environmental Health Perspectives*, researchers exposed albino rats in cages to light from a blue LED, 6500K white LED, a 3000K yellow compact fluorescent lamp (CFL), and 6500K white CFL in 12-hour on–off cycles for up to 28 days. Although the light sources had verified SPDs and intensities, they were set 20 centimeters away from the rats and measured for 750 lux, exposing the rats to "completely different levels of blue light," Ashdown says. Furthermore, the light levels far exceeded what the rodents, which have light-sensitive retinas, encounter in reality. While blue-light-induced retinal damage was found, he notes, this study was flawed.

In fact, Ashdown, who has studied solid-state lighting and its impact on human vision since 1999, says that not one academic paper associating blue light with retinal injury "presents credible evidence that light levels encountered in everyday life will cause retinal lesions."

The real issue, says Robert Clear, a retired staff scientist with Lawrence Berkeley National Laboratory and a sitting member of the IES Roadway Lighting Committee, is that this topic requires "an intersection of two sets of expertise. The people who are knowledgeable in biology are generally not familiar enough with lighting to be able to evaluate it."

In epidemiology, the findings are even slimmer. Few studies have demonstrated the health effects of long-term exposure to blue light or yielded evidence of a connection to increased risk for AMD. "Maybe one out of 20 will show there's a possible linkage," Sliney says. An often-cited example is Hugh Taylor's study of 838 Chesapeake Bay fishermen chronically exposed to sunlight, published in *Transactions of the American Ophthalmological Society* in 1990, which found only a marginal association.

Going Beyond Blue-Light Hazard

Considerable research has focused on the impact of short-wavelength light on the eye's functions unrelated to vision, such as melatonin and circadian regulation. Although light exposure in general can inhibit the release of melatonin, the hormone that signals to the body the onset of darkness or night, studies have shown that blue light seems to exert a more powerful effect. For example, boosting light levels and color temperature for 30 to 45 minutes has helped astronauts feel more awake, says Stan Walerczyk, principal of San Francisco–based Lighting Wizards, an energy-efficiency consultancy.
Other evidence suggests that nocturnal use of LED-lit mobile devices and computer displays, which emit a bluish cast, can delay sleep. Walerczyk recommends avoiding "blue light one to two hours before you go to bed." For those who can't stay away from their screens, free apps such as F.lux will

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increase and decrease the blue component in an electronic display according to the time of day, he says. Apple also offers a "night shift" option in its mobile devices that casts a hue atop screens during evening hours.

In outdoor applications, such as street lighting, LEDs with higher amounts of blue light could potentially suppress melatonin production, as the June AMA report alleges. However, the DOE and the LRC, in their responses to the AMA report, note that any conclusions to be drawn need to factor in the amount and duration of light exposure.

Avoidance Strategies

Despite the vast amount of research conducted on blue-light hazard and other blue-light-related health issues, much remains unknown about the health implications of the chronic exposure to LED light at levels encountered in daily life. However, based on a host of current international standards, such as *CIE S 009-2002: Photobiological Safety of Lamps and Lamp Systems* and *ANSI/IES RP-27: Recommended Practice for Photobiological Safety for Lamps and Lamp Systems*, the DOE has found no risk of blue-light hazard in LEDs or any other source used in general lighting applications.

All of this is not to say that the brightness of LED lighting and its blue content pose no harm to certain segments of the population, such as infants who might not avert their eyes frequently enough from light sources, and people with AMD and other eye disorders.

For the general population, Walerczyk says, "it is important to have sufficient 460 to 490 nanometers—which some people just call 480 nanometers—of light most of the day." The best way to check an LED light source's blue emission, SPD, and light output, he says, is to invest in a spectrometer and "skip CCT and CRI." •

Select Resources

"The Blue-Light Hazard: A Review," by John Bullough, *Journal of the Illuminating Engineering Society*, 2000.
"Optical Safety of LEDs" fact sheet, U.S. Department of Energy, 2013.
"Retinal Sensitivity to Damage from Short Wavelength Light," by William T. Ham Jr., Harold A. Mueller, and David Sliney, *Nature*, 1976.
"White Light-Emitting Diodes (LEDs) at Domestic Lighting Levels and Retinal Injury in a Rat Model," by David Sliney, *Environmental Health Perspectives*, 2014.
"SSL Postings: LED Street Lighting," by the U.S. Department of Energy, June 21, 2016.

ABOUT THE AUTHOR


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An independent writer and editor, Alice Liao has covered the building and design industry for more than 15 years. She is a former editor of *Architectural Lighting* and *Kitchen & Bath Business*. Her articles have appeared in several publications, including *EcoStructure*, *SNAP*, and *Hamptons*.