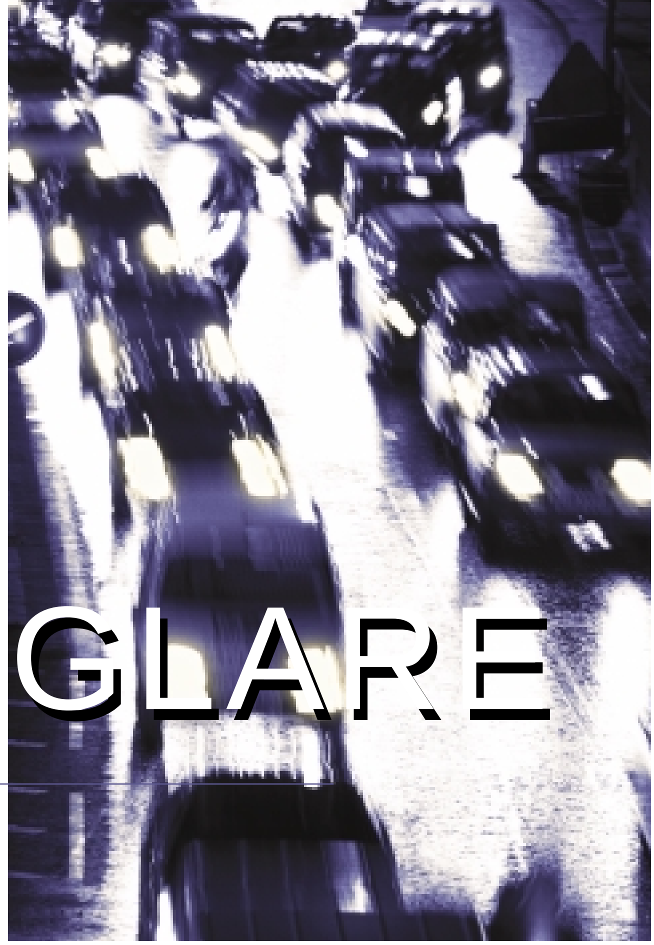

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shedding light on GLARE

Analysis reveals the advantages and drawbacks of high-intensity blue headlamps.

The prevalence of so-called blue headlamps is increasing on North American highways. These headlamps typically use high-intensity discharge (HID) or blue-filtered halogen sources, which in comparison to conventional halogen headlamps have a higher correlated color temperature resulting in a cooler color appearance. HID sources, or metal halide sources, have higher luminous efficacy, longer life, and greater light output than conventional headlamps.[1] The blue-filtered halogens have about the same light output as halogen headlamps and slightly lower luminous efficacy because the filters absorb some light, and the lamp wattage is generally increased to compensate for losses by the filter.

The U.S. National Highway Traffic Safety Administration (NHTSA) published a request for public comments on headlamp visibility and glare (log on to dms.dot.gov, click on "simple search," and enter 8885 for the docket number), and received more than 4000 responses, most of them complaining about increased glare apparently caused by these new headlamps. At the same time, a small but vocal minority—generally people who have used the new lamps while driving at night—are in favor of the new technologies. The Lighting Research Center (LRC) at Rensselaer Polytechnic Institute (Troy, NY) has been conducting research to help find the proper balance between the potential visual benefits of these lamps and possible drawbacks.

looking forward

Regulations for low-beam headlamp luminous intensity have fairly strict requirements on the necessary shape of the headlamp beam pattern in the central part of the beam. The requirements are less stringent in the periphery of the beam, where such illumination is most likely to cause glare to oncoming drivers. Because of these regulations, the luminous intensity of HID headlamps is usually similar to that of conventional halogen headlamps near the center of the beam, even though HID headlamps typically produce twice the light output as halogens. The remaining light output is generally directed to the beam periphery (see figure 1 on page 18).

Given the distributions of light shown in figure 1, it should not be surprising that HID headlamps tend to result in faster and more accurate detection of peripheral targets found beyond 5° to the left or beyond 10° to the right of the driver's line of sight.[2] But is the improved peripheral detection performance with HID headlamps caused solely by their greater peripheral light output? The spectral sensitivity of the peripheral retina at light levels typically experienced during nighttime driving is not characterized solely by the photopic luminous efficiency function $V(\lambda)$, which represents the combined spectral sensitivity of the cone photoreceptors in the retina (and has peak sensitivity near 550 nm), nor by the scotopic luminous efficiency function $V'(\lambda)$, which represents the spectral sensitivity of the rod photoreceptors in the human eye (with peak sensitivity near 500 nm; see figure 2 on page 18). Rather, the peak sensitivity of the peripheral retina at typical nighttime light levels is between 500 and 550 nm, representing the combined spectral sensitivity of the rods and cones working together.

Light sources with higher rod-stimulating (scotopic) spectral content have been shown to result in improved peripheral

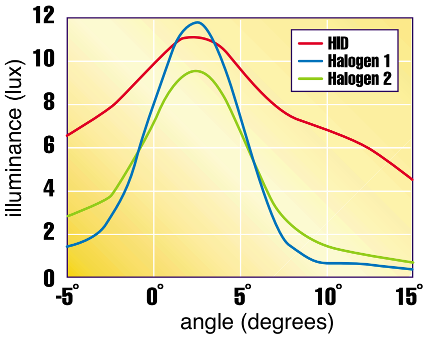

Figure 1 Plots of illuminance as a function of angle from headlamps on vertical targets positioned at ground level, 60 m ahead, demonstrate that significantly more illuminance is directed into the beam periphery for HID sources compared to conventional halogen lamps. Negative angles refer to the driver's side, positive to the passenger's side, and 0° is directly ahead of the vehicle.

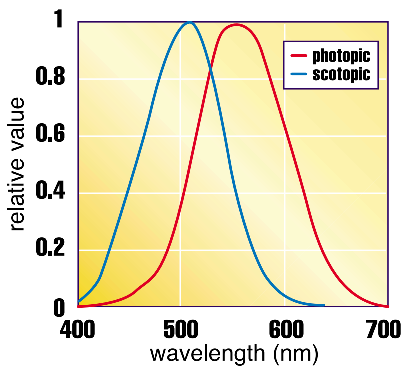

Figure 2 A comparison of the photopic luminous efficiency function $V(\lambda)$ and the scotopic luminous efficiency function $V'(\lambda)$ shows that these mechanisms have differing spectral sensitivities.

detection at these so-called mesopic light levels.[3] From a practical point of view, however, the difference between current HID headlamps and conventional halogen headlamps is so small as to be unimportant—HIDs have about 5% higher scotopic content than halogens for equal light levels, although it is worth noting that HID lamp chemistry could possibly be altered to increase scotopic content. This effect might not be unimportant for blue-filtered halogen headlamps, however, which can have 25% higher scotopic content than unfiltered halogen lamps at equal light levels. Indeed, the LRC has demonstrated improvements in peripheral detection with blue-coated halogen headlamps, compared to conventional headlamps producing the same amount of light and having nearly identical beam patterns.[4]

glaring problems

Glare is categorized into two types, depending upon its effects.[5] Disability glare refers to a luminous veil over the field of view caused by scattered light in the eye that reduces contrasts in the visual scene and degrades visual performance. Discomfort glare refers to the painful or annoying sensations a bright light can cause. Generally, these two phenomena are often coincident, especially for the case of headlight glare, but this is not always the case. A window in an office can create disability glare without obvious discomfort; conversely, a bright light could be uncomfortable without necessarily impairing visibility.

Recent data collected by the LRC during field studies conducted for NHTSA has shown that the spectral power distribution of oncoming headlamps makes no significant difference in terms of their effect on the detection of targets, whether the targets are near or far from the line of sight. The same is clearly not true, though, for discomfort glare. Using a subjective rating scale to quantify discomfort from oncoming headlamps during the same field studies, observers consistently rated HID headlamps as more uncomfortable than halogen or blue-filtered halogen headlamps. These results are consistent with many other studies of discomfort glare and headlamp spectral power distribution.[6] The visual mechanism for discomfort is still not well understood. One hypothesis is that short-wavelength cones (which have peak spectral sensitivity at 440 nm) play some role in discomfort glare, since ratings of discomfort are highly correlated with the energy from a glare source near 440 nm.[7] It also remains to be seen whether the increased discomfort actually has any indirect negative effects on driving performance.

For decades, incandescent headlamps were the only types available. In the 1960s and 1970s, as halogen headlamps with a slightly "whiter" appearance became available, complaints about increased glare as well as reports of improved visibility abounded. As halogen headlamps became more common, the hubbub surrounding their use died down. With more recent developments, including HID and blue-filtered halogen headlamps, history seems to be repeating itself. But at this point, no one can really say whether the controversy and excitement surrounding these technologies is much ado about nothing. Future research will assist in the optimization of the headlamp system to maximize forward visibility while minimizing glare. **oe**

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SPIE member

Acknowledgments

The LRC research studies described in this article were supported by NHTSA under the direction of Michael Perel, by Philips Automotive Lighting under the direction of Josef Schug, and by OSRAM SYLVANIA under the direction of Susan Callahan.

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