Color Stability Is Still a Question

by James Brodrick

As SSL applications grow, there should be no compromise on color shift

Color stability is a key characteristic of lighting, regardless of the source type, and some lighting technologies tend to maintain their color better over time than others. The rapid emergence of solid-state lighting (SSL) has raised the question of whether—and how much—color shift is an issue for LED sources. A new report from the U.S. Department of Energy (DOE), *Color Maintenance of LEDs in Laboratory and Field Applications,* considers the matter in detail and is available online at *www.ssl.energy.gov/gatewaydemos_results.html*.

Although SSL technology continues to improve on multiple fronts, the color stability of LED lighting products—especially beyond 6,000 hours of operation—remains a question. This may not matter for some applications, but for those that involve visually demanding settings—such as stores, medical examination rooms and museums—color maintenance is an important consideration, and a light source that shifts in color too much over time is just as useless as one whose lumen output drops below an acceptable threshold. The same holds true for applications in which multiple lamps or luminaires must evenly illuminate a surface that's relatively monochromatic, such as a building façade or architectural cove.

DESCRIBING AND ASCRIBING

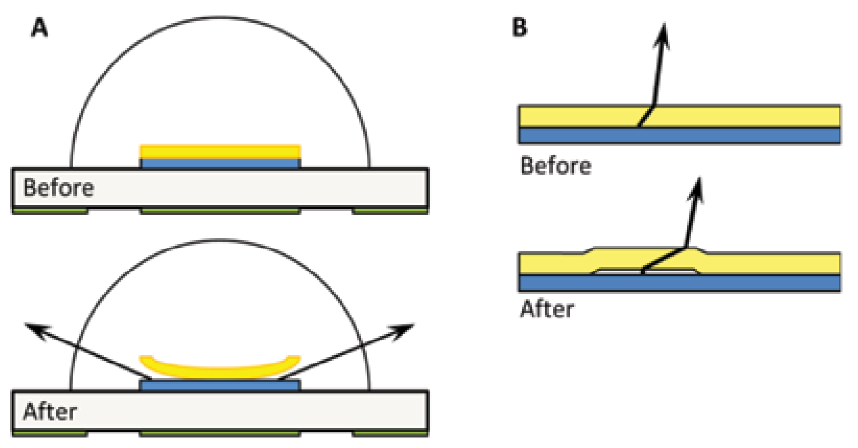
The most accurate metric to describe the color shift of a light source is Δu'v'—that is, the change in u'v' coordinates on the International Commission on Illumination (CIE) 1976 (u'v') chromaticity diagram, which is the most visually uniform diagram of a light source's color. Merely describing the change in correlated color temperature (CCT) or the change in D_{uv} does not do an adequate job of conveying color shift, which has no agreed-upon limit of tolerance (since that would depend on the application) and no method of projecting what it will be at a future point in time (as, for example, IES TM-21 provides a way to project lumen depreciation).

Color shift can be caused by physical changes to the LED package that reconfigure the ratio of blue pump to phosphor emission. Different LEDs can vary considerably in terms of their color stability, and some of the problems in this regard that were observed in earlier versions have been corrected in newer LED packages. One thing that's certain is that color shift is not an inevitable outcome for LED lighting products–as shown by the L Prize-winning lamp from Philips, which always had an average Δu'v' of less than 0.001 during 25,000 hours of testing (well within tolerances for just about any lighting application). But not all LED lamps are as well-designed as the L Prize winner, and some may shift in color so much that they need replacing after only several thousand hours.

PUTTING IT TO THE TEST

To explore the question of SSL color shift, DOE's CALiPER program conducted long-term testing of LED lamps and luminaires at an independent photometric lab between 2008 and 2010. Despite solid-state lighting's considerable progress since then, the results of those tests can help us better understand color shift. Although there were a few exceptions, many of the CALiPER-tested products displayed a shift along the blue-yellow axis, and unacceptable color shift (Δu'v' > 0.007) was much

SOME COMMON CAUSES OF COLOR SHIFT



Curling (A) and delaminating (B, close up) are two potential causes of color shift with phosphor-coated LED packages. Curling generally causes a shift toward blue, whereas delaminating generally causes a shift toward yellow.

more likely in products with a higher CCT. Out of 45 products, 15 of them failed the Energy Star requirement for color shift by yielding a $\Delta u'v'$ of more than 0.007 in the first 6,000 hours of operation (the products were not necessarily Energy Star-qualified).

Color shift has also figured in a number of DOE Gateway demonstrations, the most recent of which was conducted at the Smithsonian American Art Museum in Washington, D.C. In several of its galleries, the incumbent halogen lighting was replaced with LED PAR30 and PAR38 lamps. Despite a few issues with equivalency, beam angles and compatibility, the LED lamps yielded very satisfactory results for color and composition, as well as a significant reduction in energy use. But the color of some of the LED products has shifted noticeably as they've aged—in some cases, as a group; and in others, in a totally unpredictable way. Because of this color shift, some of these LED products have required replacing well before their rated lifetime, and although this is not covered explicitly by the manufacturers' warranties, many of those manufacturers have been working with the Smithsonian to help identify and remedy the problem. More information about the Smithsonian American Art Museum Gateway demonstration—including a complete report and a video—is available online at *www.ssl.energy.gov/gatewaydemos.html*.

TAKE-AWAYS

Gateway and CALiPER data have shown color shift to be especially complicated at the complete product level, where a host of contributing factors can come into play. At present, it's hard to predict the color stability of LED lighting products, although an IES committee is working on developing an approved procedure for LED packages. More research is definitely needed, and DOE will continue to investigate and share our findings. In addition to looking at known color-shift mechanisms, we'll provide guidance to end users on how to monitor color stability in the field, and what to look for along those lines in product warranties. This will also help in the development of needed standards that further our understanding of color performance over time, and how we communicate it.

As more and more LED lighting products are installed in buildings, long-term performance issues such as color shift will become increasingly important. While it may be convenient to overlook color stability in favor of improved efficacy or lumen output at the time of installation, the ability of LED products to achieve satisfactory performance over time will contribute greatly to their increased adoption. SSL's capability for excellent color stability has already been demonstrated, so as the technology continues to develop, there should be no need to compromise in that area for other performance attributes.

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