SSL *Postings*

U.S. DEPARTMENT OF ENERGY

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Improving Down-Conversion

When people in the industry talk about LED lighting, they’re usually referring to lighting that uses LED packages. But it would be more accurate to call such devices “LED and phosphor,” since the phosphor is actually generating more than half of the photons that we end up seeing. The way it works is that the actual LED converts injected electrons to either blue or violet photons, and then a phosphor layer — typically resting on top of the LED — converts a portion of those photons to green and red, with the resulting color mix perceived as white by the human eye.

That's what phosphors do: they convert more-energetic photons to different, less-energetic colors — which is why the general process is called down-conversion. So phosphors are a critical part of most white-LED systems. As such, they need to be not only efficient in converting photons, but also stable with respect to time and temperature, compatible with the LED package materials, and (particularly for red phosphors) spectrally narrow.

Fortunately, scientists have developed phosphors that have most of these properties, and that create white light offering a variety of color points and color qualities. But in order to reach the full technical potential for phosphor-converted LEDs (as reflected in the efficacy targets identified in DOE’s SSL R&D Plan), we need to do much better. For example, the red phosphor materials in use today are fairly efficient and generally stable, but they could be less thermally sensitive to avoid color shift and efficiency drop-off with temperature. And if they had a narrower spectral width, they would emit 10–20% more lumens, while maintaining good color quality. Plus, they need to become more efficient at converting photons. The LED-phosphor system could also benefit from a green phosphor that has a narrower spectral width, but since green phosphors emit right at the human eye’s peak spectral response, this would be of less benefit than improvements to the red phosphor.

Phosphors aren’t the only materials that could be used as down-converters. Scientists are developing alternative materials called quantum dots that are more tunable than phosphors, in terms of emitted wavelength, and are spectrally purer (i.e., have a narrower spectral width). Quantum dots have also demonstrated very high conversion efficiencies that match those of existing phosphor materials.

Although quantum dots still need further development to make them more stable and less sensitive to high operating temperatures, they represent an alternative pathway to meeting DOE down-converter performance targets and our ultimate LED performance targets.

Ongoing R&D conducted by most LED manufacturers demonstrates the importance of down-converters to the LED system. At DOE's 12th annual SSL R&D Workshop, held in San Francisco in January, there were three presentations on novel red down-converters. Two of the presentations were on new phosphor materials with good efficiency, stability, and narrow spectral width, and the third was on research into red quantum dot materials. DOE has supported this R&D topic for several years, and it has been prioritized again this year in our updated SSL R&D Plan. High-performance, high-value SSL products require an integrated approach: all elements of the system, from the LEDs to the down-converters to the optical system and thermal management, must be optimized to work together for optimal performance. And while we've come a long way, there are still important improvements that can be discovered and applied.

As always, if you have questions or comments, you can reach us at postings@akoyaonline.com.