SSL Postings
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All Fired Up About Down-Conversion

As you probably know, the process of down-conversion by phosphors has been central to the development of white-emitting LEDs. That's because, for most white-LED systems, the LED emits blue photons, most of which are converted to green-yellow and red by a layer of phosphors that typically rests on top of the LED, with the resulting color mix perceived as white by the human eye.

This process, by which photons are converted from more-energetic colors to less-energetic colors, is known as down-conversion. And while down-conversion phosphors have progressed considerably over the past decade, they still need significant improvements in order to meet the performance targets described in the DOE SSL R&D Plan. That's especially true for red phosphors, which could benefit from being less thermally sensitive and having a narrower spectral width to better match the eye response. With DOE R&D support, GE has commercialized a promising narrow red phosphor, PFS, that's making its way into GE lighting products with excellent color quality and efficacy. Another narrow red phosphor that has made it into LED products with similar benefits is the SLA phosphor developed by Lumileds.

However, phosphors aren't the only materials that can be used as down-converters. For quite some time now, scientists — some of them funded by DOE — have been working on developing alternative down-conversion materials called quantum dots (QDs), which are more tunable than phosphors in terms of emitted wavelength, and can be spectrally purer (that is, they have a narrower spectral width). In addition, QDs have demonstrated very high conversion efficiencies that match or exceed those of existing phosphors.

QDs are engineered materials that convert light through a different process than do phosphors, which are limited by their own material emission and absorption properties, whereas QDs re-emit light as a function of their size. What's more, the ability to develop specific sizes of QDs gives them the potential for greater spectral control. For the past few years, QDs have been used in TV displays, because their narrow emission expands the color gamut, resulting in a more vivid image. However, the rapid degradation of QDs under on-chip LED operating conditions — notably, high temperature, humidity, and blue-flux intensities — has been the biggest barrier to their use as a narrow-band red solution for white LEDs in general illumination applications.

That barrier appears to have been overcome — or, at least, to be toppling. Scientists at Lumileds, reporting in the journal *Photonics Research*, say they've used red QDs with tunable peak emission and narrow spectral width to demonstrate the first commercial production-ready white QD LEDs for the general illumination market. This has resulted, they say, in LED efficacy improvements of 5–15% over commercial phosphor-based

LEDs, at CCTs that range from 2700 K to 5000 K —and without the degradation that plagued previous attempts.

In other words, up until now, no one had been able to successfully deploy QDs on chips, because of the degradation from the flux, temperature, and moisture. Lumileds has succeeded by using QDs that are developed by Pacific Light Technologies and are able to withstand the extreme environment of a conventional LED package, while showing similar stability as the phosphors that they're displacing.

This is an important breakthrough, because it puts a whole new technology in the LED lighting toolbox, enabling higher luminous efficacy and even more refined control of the emission spectrum for down-converted LEDs. DOE is currently funding an R&D project at Columbia University that aims to further improve the manufacturability of the QDs that were used to get this result, and Lumileds is planning to commercialize the breakthrough.

The development of quantum dots illustrates the importance not only of taking an integrated approach that considers all elements and requirements of the system, but also of casting a wide net for R&D that takes into account alternative approaches that can help improve SSL performance.

Best regards,
Jim Brodrick

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