A novel broadband spectrally-dynamic LED

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A novel broadband white light with a tunable power spectrum, based on a dual-emitter light-emitting diode, has been developed for solid state lighting applications.

A tunable white light source based on a dual-emitter LED (light-emitting diode) has been developed for solid state lighting (SSL) applications. Next-generation illumination based on LEDs has the potential for longer life, lower power consumption, and greater efficiency. Their smaller size and enhanced controllability offer designers more freedom to create novel devices and fixtures while adding new functionality to illumination systems. Energy savings and an associated reduction in greenhouse gas emissions are additional advantages. The success of solid state lighting (SSL) will depend on the development of novel sources that will allow it to offer additional features over and above its use as a replacement for incandescent or fluorescent lighting.

General illumination requires high color-rendering capabilities and appropriate color temperature. Therefore, it is important to eliminate gaps in the power spectrum of typical LED sources to achieve high-quality white light. For example, Figure 1 shows the drastic difference between the power spectra obtained using clusters of standard RGB (red-green-blue) LEDs and a diurnal variation of a broadband source that mimics the range of daily sunlight. Tuning the blue source would allow more control of the broadband source over a 24 hour period.

In this study, two LEDs, emitting at distinct wavelengths (400nm and 460nm), are individually grown and used to excite two or more phosphors. These have different excitation spectra and the relative intensities of the pump peaks allow dynamic tuning of the correlated color temperature (CCT). Such a device combines the controllability of RGB-LEDs and the broadband characteristics of phosphor-converted light-emitting diodes (PC-LEDs).

The GaN LED emission wavelengths of 400nm and 460nm were chosen because they produce the desired output spectrum. The phosphors used have included: (A) UV to white, (B) SrGa2S4, (C) SrCa:Eu. Each was excited by the 400nm and 460nm light, both independently and simultaneously. Phosphor A was strongly excited by 400nm and not 460nm, while the opposite was true for Phosphor C. Phosphors A, B and C were then combined based on the results to achieve a source with a CCT similar to an incandescent bulb. Finally, the dual pump wavelength source was used to excite the phosphors. At the same time, the relative intensities of the two wavelengths were varied from 460nm only to 400nm only via intermediate states including equal pumping by both wavelengths. Figure 2 shows an increase in the yellow/green (~560nm peak) phosphorescence with an increase in the relative intensity of the pump.

Figure 3 shows the various broadband spectra plotted on a 1931 Commission Internationale De L’Eclairage (CIE) diagram showing the variation in color achievable with this combination of phosphors. With the 400nm pump dominant, more of the yellow/green component is observed. Continued on next page
Figure 2. The arrow indicates that the yellow section of the spectrum is increased due to the change in phosphorescence with constant 460nm emission and changing 400nm emission.

Figure 3. Using a 1931 CIE diagram, we show the full range of phosphor combinations plotted, with an incandescent point shown for reference.

low/green phosphor is excited, moving the color coordinates closer to the yellow edge of the spectrum. Increasing the relative intensity of the 460nm pump excites more of the red phosphorescence as well as adding blue light from the pump to the spectrum. This shifts the color coordinates toward the violet edge of the CIE diagram. A large area of the color diagram can be accessed with this combination of phosphors and pump choices. In addition, CCTs ranging from 3588K to 4793K are achievable. It is important to note that high color rendering indexes (CRI), of 85 and 82 were achieved. These rival many fluorescent lamps, and can be attributed to the broad emission from the combined phosphor.

This work shows the potential for a broadband spectrally dynamic SSL source using multiple phosphors. However, more work is required to understand the interaction between the two wavelengths of light and the combination of phosphors in order to control the output of the source accurately. Innovations such as this will help SSL gain a competitive advantage over conventional illumination sources.

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References