Efficient LED luminaire offers controlled illumination

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Advanced diffusion technology facilitates the development and marketing of LEDs for use in general lighting and specialized illumination applications.

The advantages of LED sources for a wide variety of illumination applications are widely acknowledged and aggressively touted. Behind the hyperbole lies the fact that LED lighting will eventually come to market at lower cost that current technologies while providing longer life, unmatched color quality, and unprecedented control over production and modulation of arbitrary spectra. Industrial and academic researchers alike are investigating LEDs for uses ranging from mundane applications such as street lighting to esoteric illumination systems with spectral distributions that affect circadian rhythms.

The advent of LEDs for general lighting will cause a large-scale economic impact. These sources will replace conventional lamps in homes, offices, and businesses. For this to happen, however, technology must advance on at least two fronts. LED efficiency must improve and, in addition, optical elements for light control and distribution must be further developed. When performance and component pricing start to rival conventional sources, then the energy savings and long-term cost benefits will provide strong motivation for the transition to LED.

For several years RPC Photonics\(^1\) has been working to develop what it calls engineered diffusers (EDs)\(^2\) that are especially suited to LED sources.\(^3\) As opposed to common diffusers such as ground glass or holographic films, EDs enable measured distribution of light into specific regions of space with simultaneous control of intensity (see Figure 1). EDs are actually deterministic diffusers that employ microlens elements as their basic scatter units.\(^2\)

An ED can homogenize general sources, whether collimated or not. However, greater control over light distribution and intensity requires some degree of collimation. In the example shown in Figure 1, the LED source was initially collimated to ±5 degrees with a simple lens. This approach, however, is not ideal. At the die level, LEDs are essentially Lambertian sources that scatter light over the entire hemisphere, which a simple lens cannot collect efficiently.

As a collimator-diffuser, the ED can address the issue of collecting virtually all energy emitted by the die while at the same time enabling maximum control of light distribution.\(^4\) It can be integrated with the source to produce a compact, ultra-thin luminaire for general lighting. The basic concept is illustrated in Figure 2. Instead of aligning the LED light with a lens, a collimating structure is used to collect and direct all light towards a front surface upon which is mounted an ED. The whole assembly can be integrated as a single set of components and, for improved flexibility the ED is a detachable element that can be replaced depending on the desired properties of light to be produced. It is even plausible to imagine a plate with designs that can be remotely moved over the collimating element to provide varied illumination patterns.

We assembled a collimator with a product by OSRAM Opto Semiconductors, the Golden Dragon® green LED, which emits about 20lm/W with a Lambertian profile (see Figure 3). This design, when collimated to about ±4 degrees, has output distribution that can be combined with an ED to provide controlled illumination, as shown in Figure 4.

To produce a luminaire, we now put together a cluster of collimator and diffuser elements, or else collimators and separate diffusers that can be attached to the cluster to generate a...
Figure 2. The basic collimator/ED is integrated with an LED source as a single unit.

Figure 3. This LED/collimator assembly can employ an ED for controlled illumination as charted in Figure 4.

Figure 4. Controlled illumination with EDs from collimated light emitters. (a) Two diffuser designs are measured with laser light and produce distinct scatter behavior. (b) The profile is much smoother when measured with the LED and collimator.

Figure 5. Various luminaire configurations can be designed for larger light fixtures.

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References