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Points of Light with Chris Bailey

Optical Illumination: An Interview with *Architectural Lighting*

After some initial grappling with LED technology, the lighting industry is leveraging its distinct performance and potential.

As LEDs have taken the lighting market by storm, manufacturers have been quick to sell this new illumination source principally on the basis of its efficacy. Implausible lumens-per-watt packages became plausible, and lighting specifiers and end-users alike were intrigued. “We were all kind of drunk on efficiency,” says Chris Bailey, a solid-state lighting technology strategist and director of the Lighting Solutions Center at Hubbell Lighting.

Consequently, in the rush to get products on the market, little attention was given to the optical distinctions and opportunities offered by solid-state lighting early on. Original equipment manufacturers (OEMs) and lighting manufacturers designed LED fixtures to look and function just like other luminaires in the 130-year history of electric lights, Bailey says. “Because the technology wasn’t what it is today, we sacrificed some of the human response to the product. [We generated] light, but don’t look up.” While the goals of comfortable, glare-free, and uniform lighting hold true, manufacturers and fixture designers are re-charting their course.

Deciphering the Differences
To understand how LEDs differ from their conventional (filament) light-source counterparts, you first need to know how they work. Diodes are polarized semiconducting chips that generate photons through electroluminescence, or via an electric current. Incandescent lamps create light through radiance or heat.

Light distribution is another distinction between the types of sources. While conventional lamps distribute light spherically, in 360 degrees, LEDs have a 180-degree distribution.

An LED’s directional, forward-throw of light means retrofitting a conventional fixture isn’t a matter of simply switching the source. For example, reflectors intended for an incandescent or compact fluorescent lamp would be rendered useless, in part because LEDs aren’t sending any backlight for the reflectors to redirect. In most retrofit cases, Ngai says, “the distribution will be very different. In order to properly retrofit an existing luminaire with LEDs, one would need to replace prior reflectors, lenses, or other internal optics with new designs that are appropriate for LED sources.”

Quantity matters too. LED luminaires use multiple diodes or “miniature lamps” whose luminance they have to collect and redistribute appropriately, Bailey says. Each point source “packs a lot of lumens,” creating ample opportunity for discomfort glare and a distribution that looks pixelated rather than continuous and uniform.

Fallback Devices
With conventional lamps, manufacturers use a combination of a lens and a reflector to deliver light to the target and diffuse the luminance. Though these optical devices, such as a sandblasted glass dome, may reduce light output by as much as 50 percent.

With LEDs, as in conventional lamps, delivering glare-free light requires enlarging and diffusing the light source. Subsequently, LED fixtures typically have two optical layers: a primary optic, such as a dome-shaped lens that extracts and distributes the light in accordance with the desired photometric specification; and a secondary optic to collimate, diffuse, direct, or control the light if it needs further distribution and directionality. This secondary optic also dutifully increases the source size. Conversely, the primary optic may be the diffuser and the secondary optic may be the lens or reflector that directs the light.

Tweaking Old Technologies

Regardless of the optics employed—which will depend on several factors including application—the key to using light efficiently is allowing it to exit and reach its target. Because the emission of light from an LED is contained within 180 degrees, lens optics work well for controlling output. The diminutive size of an LED also means that a complete lens is about equal to the size of the light source and can be used in lieu of a compact or Fresnel lens to collimate the light. As a result, the light output is less compromised—or scattered—from the start.

Manufacturers are also improving the quality of lenses. “We’re changing the interior surface of the lens to have more of a matte finish,” Bailey says. “We’re eliminating a lot of the bounce light that would normally be reflected off of the inside finish of the lens.”

Improvements in diffuser technology have also enabled greater control of light while maintaining efficacy. Rather than sandblasting or embedding diffusive particles in glass or polycarbonate, manufacturers can mold plastic lenses with surfaces and shapes tailored to the LED’s application, and potentially decrease the amount of light lost to less than 10 percent.

Because an LED outputs relatively little heat in a forward direction, it can be positioned closer to the lens or diffusing medium. This provides the opportunity for a smaller overall luminaire that can work with materials such as film and wood veneer, which were previously incapable of sustaining the high heat levels generated by conventional lamps, Bailey says.

Lighting manufacturers and OEMs also use parabolic and hyperbolic reflectors to block the LED source from view, reduce glare, and direct light. However, the parabolic shape, though successful in capturing enough light from lamps with spherical distributions, can miss spill light emanating near a lamp’s central axis—a significant proportion of light for LEDs given their 180-degree distribution. As a result, some lighting manufacturers are experimenting with different orientations for LED arrays inside the parabolic reflector to improve control of light output.

In With the New

Existing optical technologies aren’t always adequate for the desired lighting application. Manufacturers are now exploring the potential of refractive technologies. “We’re developing prisms versus reflectors,” Bailey says.

Total internal reflection (TIR) optical devices combine a reflector and a refractive lens to control direct and reflected light from an LED. Light beams from the LED’s central axis enters and exits through the refractive lens, while TIR surfaces handle perimeter lighting.

By capitalizing on internal reflection, fixture designers can also use edge lighting to distribute the intense LED light though the luminaire body itself in what is called a lightguide. Lighting manufacturers are also experimenting with holographic films made from materials such as polycarbonate and polyester. The microstructure of these diffusers can eliminate LED imaging and pixelation, shape the distribution of light to myriad beam angles, and transmit light efficiently.

Injection-molded acrylic and plastic optical devices, designed to distribute and diffuse the light in a specific manner, are garnering interest from LED and lighting manufacturers as well. Optical engineers are experimenting with microfacets and microfeatures on lenses. “These nearly invisible features on the optics will have massive implications in terms of how the light exits the product,” Bailey says.

The size, efficacy, and reliability of LEDs have opened doors to a realm of optical and luminaire designs that manufacturers are only beginning to realize. Marveling at concurrent lighting advancements in technologies such as electroluminescence and remote phosphors, Bailey says the industry has “been reborn in the light. … It’s been a very inspired time where we have the freedom to take this new technology and create beautiful light with it.”