Transitioning to Solid-State Lighting: A Focus on Solutions

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For many companies in the LED lighting industry, the mission for solid-state illumination is to reinvent lighting by leveraging the benefits of light emitting diodes. We foresee that LEDs will be more energy efficient and will reduce the use of hazardous materials in lighting. They will enable smaller fixture designs and new approaches to general and task-specific lighting. LEDs will trigger technological revolutions analogous to flat-panel televisions and solid-state data storage. Compared to today's sources, LEDs will excel at color rendering and contrast. They will fully integrate lighting and electronics, while requiring minimal maintenance. The path to this exciting future will not be paved by shoehorning LEDs into current lighting designs and concepts. This approach takes the path of least resistance at the expense of the solution. A state-of-the-art LED program focuses on the end goal by understanding customers' design requirements, providing the means to overcome each application's challenges, and executing the most effective solutions.

To fully explore the benefits of LEDs, all details of light quality and efficiency must be considered. This ranges from generic characteristics such as intensity, efficacy, wavelength (or color temperature), and emission pattern, to further refinements such as lumen maintenance, allowable intensity range, allowable color change (as defined by MacAdam ellipses), and both diode-to-diode and array-to-array consistency. Generating proper light quality also depends on aesthetic requirements such as hot spot criteria, brightness uniformity, and whether the lighting is viewed directly or indirectly. LED sources are regulated by organizations such as ANSI, IESNA, CIE, FCC, NFPA, and UL— requirements are application-dependent. Additional energy objectives such as the Energy Star program also impact LED technology.

Mechanical and electrical requirements impact all aspects of every design. The design envelope impacts nearly all applications. To address thermodynamics, the operating temperature range must be defined. Materials are selected based on conditions such as humidity, temperature cycling, and chemical environment. A detailed analysis of electrical characteristics is also required for a sound lighting solution, and input characteristics such as voltage, current, supply range, and stability are required. Many applications have specific requirements for power factor, peak voltage, peak current, and electrical isolation. Electronic lighting makes dynamic programming like color mixing, dimming, and feedback circuits such as fault indicators possible.

All of these inputs must be appropriately balanced, along with cost considerations. The objective is to design efficiently. For example, customers generally get the most return on investment by focusing on their thermal path from substrate to ambient—high-cost, high conductivity substrates only make sense when the application justifies them. A premium substrate may impact the junction temperature by 5-10˚C over standard materials or FR4, whereas premium thermal management at the next level can be an order of magnitude more effective.

To achieve the best solution, we must be able to quantify performance quickly and accurately. A fully equipped, onsite LED lab is required to perform the necessary evaluations that continually refine our technological database. For example, OPTEK Technology houses an LED lab that benchmarks the performance and reliability of most high-power LEDs across the industry for all optical characteristics by collecting ongoing lumen and color maintenance data. Since accurate, useful life test data requires precise temperature control, these tests are conducted on thermoelectric cold plates to achieve junction temperature stability within 1˚C. These thermal test systems support thermal benchmarking for components and substrate materials as well.

All designs for each application are verified in the lab. Circuit boards can be manufactured internally so that prototypes are generated on FR4 or metal-core substrates within one day. Faster prototyping accelerates design refinement by providing empirical results and putting physical units in the customer's hands. Our lab supports assemblies up to 18" in length and allows characterization of all aspects of optical, mechanical, thermal, and electrical characteristics.

A successful approach is best illustrated by exploring the challenges that solid-state lighting designers and manufacturers,

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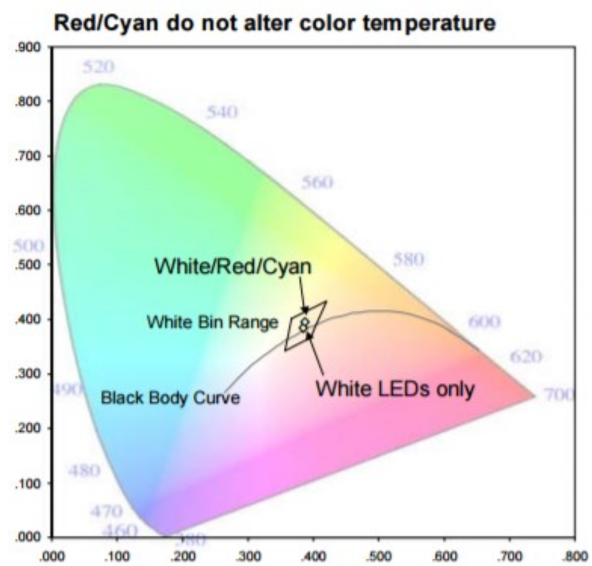
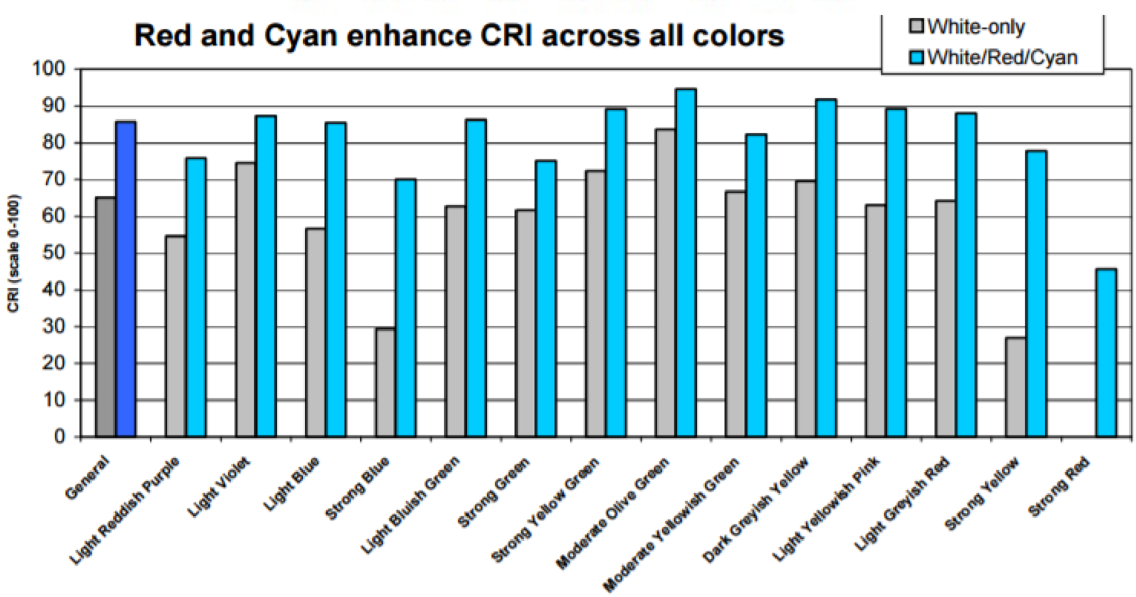
including Optek, have overcome. One customer sought a metal-halide dock light replacement with a minimum of 4,000 lumens, color temperature uniformity within 200 K, CRI above 80, and system efficacy exceeding 45 lm/W. Their goal was to leverage LEDs as a means to reduce power consumption and promote greener shipping. To achieve these requirements, Optek mixed high-efficiency white, red, and cyan LEDs to enhance the CRI without sacrificing efficacy or changing the color temperature. We optimized the relative intensities of each type of LED to achieve the highest CRI possible. Additionally, developing a custom, dimmable driver solution and circuit design reduced power consumption by eliminating the need for board-level current regulators and allowing the brightness to be adjusted depending on the time of day.





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To achieve the required consistency in production, Optek inverts the standard planning system. Typically, a manufacturer fills a bill of materials based on the product's specification, but for this application, available materials set the plan. The intensity, color temperature, wavelength, and forward voltage bins of white, red, and cyan LEDs on hand dictate the rest of the bill of materials. Over 100 potential bin combinations are resolved into final assemblies with enhanced color rendering and consistent array-to-array output in each lot. With inverted planning, we achieve the high standards of individual bin selection while retaining the sustainability and cost-savings of accepting all bins. To get the most out of LEDs, we must excel at value-added manufacturing techniques such as the careful planning and execution that made this solution possible.

To attain the benefits of solid-state lighting, we must focus on the solution rather than the problem. It is better to ask, "How can we change the way we create light to make the best use of it?" rather than, "How can we fit LEDs into yesterday's technology?" Resistance to change is expected, and for LEDs it must be overcome. LEDs enable new and better ways to look at efficiency—lumens per Watt is only informative if those lumens translate to useful light in each application. LEDs can achieve extremely efficient translation from power supplied to useful light produced. Inevitably, such designs will achieve the most important type of efficiency: lumens per dollar.

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