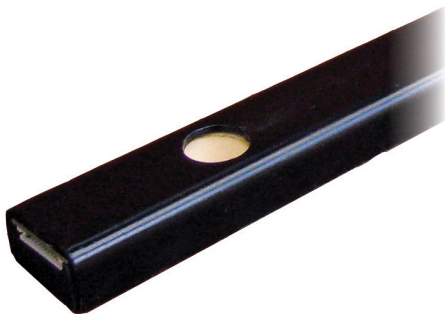


Denmark's Crown Jewels Get Lighting Makeover, Aided by Future Lighting Solutions' LED Support

Incandescent lighting is being replaced by LEDs in the display cabinets at Denmark's Rosenborg Castle to reduce energy consumption and beat the heat inside the cases.



One of the challenges of lighting gold objects with LEDs lies in achieving the warm color temperature necessary to make the gold glow. For Copenhagen's 17th century Rosenborg Castle, that challenge was compounded by a variety of special considerations involved in illuminating Denmark's crown jewels. In 2009, two Danish lighting companies working with Future Lighting Solutions and DTU Fotonik, the department of Photonics Engineering at the Technical University of Denmark, delivered a fixture that filled the bill by combining LUXEON® Rebel LEDs, sophisticated color spectrum analysis, and a proprietary optical mixing strategy. The resulting light strip – now sold under the name PinolLED – not only put the gleam in the gold but also slashed energy consumption by 80% and eliminated the incandescent heat load that threatened to damage the royal relics. In addition, it provided a solid-state alternative for illuminating gold, fine fabrics and precious gems – just in time for the EU's ban on incandescent bulbs.



I-NO's PinolLED light strips utilize warm white and red LUXEON Rebel LEDs with a proprietary optical mixing strategy to achieve the required color temperature and values.

INCANDESCENT ANXIETY

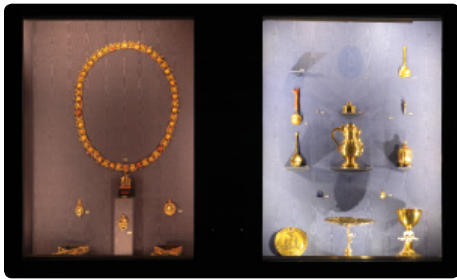
The Treasury room of Rosenborg Castle houses a collection of crown jewels and decorative objects accumulated during 300 years of Danish royal rule. From a 1305-carat amethyst to brooches, tiaras and jewel-encrusted crowns, most of the collection is mounted inside illuminated glass cases affixed to the walls. Originally, the illumination inside the display cabinets was supplied by incandescent light bars running at reduced voltage to achieve

“The success of this project is directly related to our ability to obtain detailed color data on LUXEON Rebel LEDs as well as advanced color binning from Future Lighting Solutions. Without those services as well as Future’s logistics support, we would not have been able to bring this fixture to market.”

Peter Selmer Gade, CEO, I-NO

the candlelight-equivalent 2200K color temperature considered optimal for lighting gold. But all that glitters is not perfect.

First, the temperature inside the cases was 12 degrees higher than in the room itself because of the incandescent-generated heat, raising concerns that the fragile fabrics in some of the artifacts would deteriorate from fluctuations in humidity caused by varying temperatures. Second, the intense heat turned the gold black when touched, requiring continuous polishing. The lighting also burned excessive energy and made the showcases’ royal blue backdrops appear gray, lessening the regal impression as well as the overall eye appeal.



I-NO’s LUXEON-based luminaires were specially engineered to bring out the blue of the showcases’ backdrop (right), which washed out to gray under incandescent illumination (left).

The castle management’s search for a solution began with Lumodan, a Danish LED lighting distributor that does a lot of work with castle and museum lighting. Lumodan enlisted the assistance of DTU Fotonik to develop an LED-based replacement light strip that would take advantage of both the lower power consumption and cooler light beam of LED technology. The R&D would be funded through Denmark’s Public Service Obligation program, which provides subsidies for new energy-saving technologies under the Danish Energy Association (PSO: 339-025).

COLOR MIXING CHALLENGE

In 2008, the Lumodan/DTU Fotonik team delivered a prototype solid-state luminaire that achieved the same 2200K color temperature as the incandescent version by combining warm white and red LEDs and then adding a carefully selected optical filter to reduce unwanted colors. The light was mixed and emitted using a proprietary optical mixing system. Hitting the 2200K mark was a technical triumph, but the light output was low, the showcase backplates still looked gray, and the LEDs had to be selected by trial and error because the vendor lacked advanced color binning capabilities.



The team then turned to Danish LED lighting engineering firm I-NO for their electronics and commercial solid-state manufacturing knowledge. In short order, I-NO recommended switching to LUXEON Rebel LEDs because of their ability to run at currents of up to 1000mA for increased brightness, the tight color binning available from LUXEON distributor Future Lighting Solutions, and the detailed documentation and inventory management that Future could provide to I-NO – as an integration member of the Future Lighting Solutions network - to identify color values and ensure reliable LED supply.

Next, the team tackled the twin challenges of beefing up the cases' blue background and simplifying the LED selection process.

“True 2200K light cannot render saturated blue colors because it contains very little blue. That’s why the blue backdrop in both the incandescent and initial LED scenarios washed out to gray. The issue was devising a way to enhance the blue without raising the color temperature,” said I-NO CEO Peter Selmer Gade. “The solution both for that and for selecting the most appropriate LED reels depended on getting a precise color breakdown for each LUXEON Rebel color bin.”



Each LED assembly contains one warm white and one red LUXEON Rebel LED, selected by color bin based on spectral power distribution data from Future Lighting Solutions.

STRIKING GOLD

To establish a color target, DTU Fotonik and I-NO measured the color levels in the incandescent-lit showcases with a spectrometer, and Lumodan solicited input on the pros and cons from museum staff and management. Then I-NO obtained spectral power distribution data from Future Lighting Solutions on all warm white LUXEON Rebel color bins and integrated the data into I-NO’s proprietary Preemptive Light Designer color mix calibration software to determine which color bins and filters would produce the desired light quality. The firm also refined the Lumodan/DTU Fotonik system design using LUXEON Rebel LEDs and custom components. The finished PinolLED system:

- Tripled the light output over the earlier LED-based prototype by driving the LUXEON Rebels at 600mA
- Deepened the cases’ royal blue background by utilizing color bins with higher blue content as well as using an optical filter that retained more blue light
- Reduced energy use by 80%, consuming just 26W per showcase compared to 150W for the incandescent originals
- Beat the heat inside the showcases, reducing the incandescent-caused 12-degree difference between the room and the cases to less than 1 degree.
- Expedited LED selection by using I-NO’s proprietary software to analyze available color bins for the desired color composition





The most valuable treasures in Copenhagen's Rosenborg Castle are housed in the Treasury room deep in the palace basement, where the showcases are now being upgraded to LUXEON-based solid state lighting.

"Our Preemptive Light Designer software generates a color mixing formula based on the characteristics of the individual color bin," Gade noted. "That means we can create the required color effects with almost any warm white LUXEON Rebel color bin simply by changing the optic filter and the drive current. There is no longer a need to make multiple prototypes from different LED bins to find the one that works."

FIXTURES FIT FOR A KING

The first of the finished fixtures were installed in a single showcase in Rosenborg Castle in April 2009, utilizing two 90-centimeter-long light strips on each side of the cabinet and two 30-centimeter-long luminaires each on the top and bottom. Each light bar contains two to four LED assemblies consisting of one warm white and one red LUXEON Rebel LED mounted on a custom-sized aluminum printed circuit board with a custom driver, an off-the-shelf filter and the proprietary optical mixing system developed by DTU Fotonik. The boards are tightly fitted to the fixture's aluminum frame for heat dissipation purposes, eliminating the need for an external heatsink.

The now-commercialized PinolLED light strips are scheduled to be installed in the castle's remaining showcases by early 2010. The luminaires are also being distributed by Lumodan in multiple lengths, primarily in Scandinavia and other areas of Europe.

With the EU's phase-out of incandescent bulbs prompting concern from merchants and museums over the inability of compact CCFL lamps to make their gold goods sparkle, the Lumodan/I-NO light bar offers a worthy option for showcase lighting. Other display environments may not be illuminating crown jewels, but the PinolLED will give any object made of gold, gems and/or fabric the royal treatment.

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