SSL IN PRACTICE

EDWARD CLARK
SSL DESIGN CHALLENGES
CONTROLS CONSISTENCY (INCONSISTENCY)
Indy™ LED Architectural Lighting
ChromaControl
Color Tuning • CCT Control • Black Body Dimming
4", 6", 8" Downlight, Adjustable, Cylinder or Wall Wash

New Construction
Remodel
Cylinder
Adjustable
Retrofit

HUMAN CENTRIC LIGHTING - TUNABLE FIXTURES
CORRELATING COLOR NOT JUST TEMPERATURE

LINEAR TUNING

Non-linear tuning products perform somewhat differently in terms of how the chromaticity changes. For the linear-tuning products, $D_{uv}$ varies as the CCT changes, meaning that the light not only changes from warm to cool, but also becomes more green or pink at various points (Figure 4). Large values of $D_{uv}$ may be undesirable, especially if they are positive below a CCT of 4000 K, but the effect of changes in $D_{uv}$ within a single product have not been studied, and it is unknown if they are acceptable to occupants.

All four nonlinear white-tuning products were relatively successful at following the blackbody locus, as shown in Figure 5, with small $D_{uv}$ values across the entire range. More interesting is the fact that they employed different methods to do so. Based only on examination of the measured SPDs, it appears that three of the products used multiple narrowband LEDs—potentially combined with a white LED—whereas the fourth product used two white or near-white PC-LEDs along with a red LED. This latter product also had the highest efficacy of the nonlinear white-tuning products, potentially because it avoided using a green LED.

Color Consistency over Dimming

While dimmed performance was not the focus of this investigation, measurements were taken at multiple intensity levels for each of the color set points. The only consideration discussed in this report is the ability of each product to maintain the full-output chromaticity of a given color set point as intensity was reduced. As shown in Figure 6, a couple of the products (15-08-D, 15-10-S) performed extremely well in this area, but several others did not. Figure 6 shows two different calculated values: the maximum change in chromaticity versus full output at any given color set point as the luminaire was dimmed, as well as the average change in chromaticity versus full output for all color set points as the luminaire was dimmed. Both provide an indication of performance, and can be interpreted together to determine the significance of the inconsistency. Especially notable are the three products that exceeded a $\Delta u'v'$ of 0.007 while they were dimmed at a single color set point. This is most likely noticeable.

Figure 5. Change in chromaticity over the color tuning range at full output for the nonlinear tuning products. All four products were successful in tracking the blackbody locus. The minimum and maximum CCT of the products varied substantially.

Figure 6. Change in chromaticity over the color tuning range at full output for the linear tuning products. Each LED must be mixed before the sum is emitted, to avoid visible color differences within the luminaire or emitted light. This mixing may be more important for nonlinear-tuning products, since they often use one or more narrowband (colored) LEDs, whereas linear tuning products mix different white LEDs with less noticeable color differences. This mixing often requires some form of secondary diffusion, which usually reduces the final efficacy. In the end, it is likely that there will always be some type of tradeoff in efficacy for the added benefit of color tunability, but as the technology advances, the differential is likely to be reduced.

Color Quality

All color metrics are calculated from the luminaire's SPD, which changes as the individual LED primaries are adjusted to provide more or less output. Appendix B provides SPDs for all color settings at full output, with one chart for each product. While color performance generally cannot be inferred just from examining an SPD, SPDs can be helpful for understanding the LED primaries that comprise each product, and how they are manipulated over the tuning range.
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**Chromaticity Change**

Color quality is at the forefront for color-tunable luminaires. With lower efficacies than traditional LED products, the changeable color is the only distinct advantage of the products tested for this report. Notably, the two types of white-tuning products perform somewhat differently in terms of how the chromaticity changes. For the linear-tuning products, $D_{uv}$ varies as the CCT changes, meaning that the light not only changes from warm to cool, but also becomes more green or pink at various points (Figure 4). Large values of $D_{uv}$ may be undesirable, especially if they are positive below a CCT of 4000 K, but the effect of changes in $D_{uv}$ within a single product have not been studied, and it is unknown if they are acceptable to occupants.

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HUMAN CENTRIC LIGHTING

- No light exposure at 8:00 AM
- Light exposure advances clock
- Light exposure increases alertness
- Light exposure delays clock
- No light exposure at 6:00 PM

MELATONIN
CORTISOL

DOE SOLID STATE LIGHTING
8:00 AM
No light exposure

12:00 PM
light exposure increases alertness
light exposure advances clock

6:00 PM
light exposure delays clock
No light exposure

BLUE WASHING

MELATONIN
CORTISOL
DOE SOLID STATE LIGHTING
3.2 IDENTIFICATION
A. Comply with requirements in Section 260553 “Identification for Electrical Systems” for identifying components and power and control wiring.
B. Label each dimmer module with a unique designation.
C. Label each scene control button with approved scene description.

3.3 FIELD QUALITY CONTROL
A. Manufacturer’s Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
B. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
   1. Continuity tests of circuits.
   2. Operational Test: Set and operate controls to demonstrate their functions and capabilities in a methodical sequence that cues and reproduces actual operating functions.
      a. Include testing of modular dimming control equipment under conditions that simulate actual operational conditions. Record control settings, operations, cues, and functional observations.
C. Remove and replace malfunctioning modular dimming control components and retest as specified above.
D. Test Labeling: After satisfactory completion of tests and inspections, apply a label to tested components indicating test results, date, and responsible agency and representative.
E. Reports: Written reports of tests and observations. Record defective materials and workmanship and unsatisfactory test results. Record repairs and adjustments.

3.4 DEMONSTRATION
A. Engage a factory-authorized service representative to train Owner’s maintenance personnel to adjust, operate, and maintain modular dimming controls. Laptop portable computer shall be used in training.
B. Coordinate demonstration of products specified in this Section with demonstration requirements for low-voltage, programmable lighting control system specified in Section 260943.13 “Addressable-Fixture Lighting Controls” and Section 260943.23 “Relay-Based Lighting Controls.”
C. Provide second commissioning and training visit by factory-authorized service representative 3 month post-occupancy to adjust system scene and fade controls and schedule.
FEAR BASED PRICING
LIBERATED FORM AND EXPANDABLE CAPACITY
LIBERATED FORM AND LOCATION
FUN, WHIMSY AND POSITIVE DISTRACTION
ENGAGE OCCUPANTS
AFFORDABLE - COMPETITIVE

DOE SOLID STATE LIGHTING
PRODUCTIVE SALARIES & BENEFITS 86.3%

ENERGY 0.8%

RENT 8.9%

ABSENTEEISM 2.7%

PRESENTEEISM 1.3%

UNPRODUCTIVE SALARIES & BENEFITS

SOURCES: US DEPARTMENT OF LABOR 2010, BLS 2011; BOMA 2010

FROM THE ECONOMICS OF BIOPHILIA, TERRAPIN BRIGHT GREEN
HUMAN CENTRIC LIGHTING

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  - No light exposure
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- **12:00 PM**
  - light exposure increases alertness

- **6:00 PM**
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  - No light exposure

**CORTISOL**

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  - light exposure delays clock
  - No light exposure

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  - light exposure delays clock
  - No light exposure
Vertical Illumination at the Eye - lux (z=42°)
View vector
(Spectral qualities of tables need to be studied.)

Threshold Response = 0.1 - 0.2 CS
Circadian Shift = 0.3 - 0.4 CS
Circadian Saturation = 0.7 CS
Rea et al.

Max
CS = 0.36 @ 6000K
CS = 0.22 @ 2200K

Min
CS = 0.12 @ 6000K
CS = 0.06 @ 2200K

*assuming neutral materials

Spectral Power Distribution of BeveLED 2.0 at specified CCT
MARCH 21 . NOON . INTERMEDIATE SKY . 5000K

Macbeth#15  Daylight
Macbeth#3  Daylight

CIRCADIAN - LUCAS

HTTP://WWW.FOOD4RHINO.COM/PROJECT/LARK?UFH

HUMAN CENTRIC LIGHTING

DOE SOLID STATE LIGHTING
THANK YOU

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