

Color Tunable LED Products: What you need to know



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Trend – Color tunable and Tunable White Luminaires

Three flavors:

- Full color tunable (RGB, RGBA, RGBW, etc.)
- Dim-to-warm, ala incandescent
- Tunable white, means range of CCTs available

Image from SuperBrightLEDs.com



Sophie's, Chicago USAI Lighting Photo: Peter Aaron/Esto



Eaton's
Cooper
Lighting

Applications: Color tunable and Tunable White Luminaires

Full color tunable:

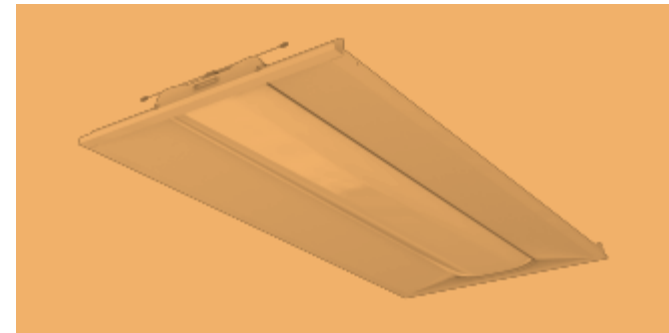
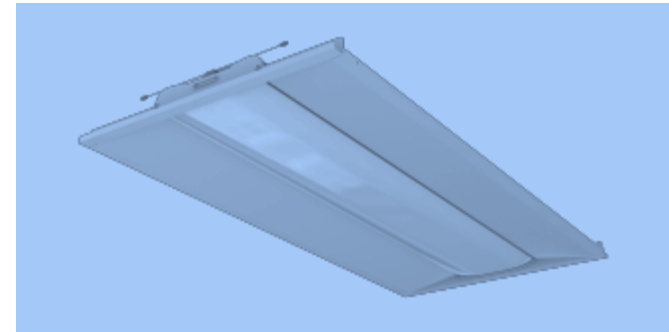
- Tuning one set of LED products in a space to match other sources in the space
- Tuning for preferred appearance of retail products (like apples)
- Creative appearance of space (3500K at one work station, pool of reddish light in corridor, wash of purplish light on lobby wall, for example)
- Entertainment (fixed or variable setting for a space with multiple functions and occupancies)

Dim-to-warm:

- Mimicking incandescent, especially when dimmed

Tunable white:

- Circadian stimulation or to suppress circadian stimulation, especially if the space has multiple occupancies or uses over the course of 24 hours
- Behavior control (calming, invigorating children in classroom)
- Circadian correction (jet lag)
- Matching color of daylight during day, warmer dimmer light in evening
- Tuning to match finish selections, especially when they change on a seasonal or regular basis
- Tuning for tenant/owner/user preferences
- Tuning to create a mood or condition appropriate for art
- Changing light color to provide apparent cooling or warming to room



Color Tunable and Tunable White Luminaires

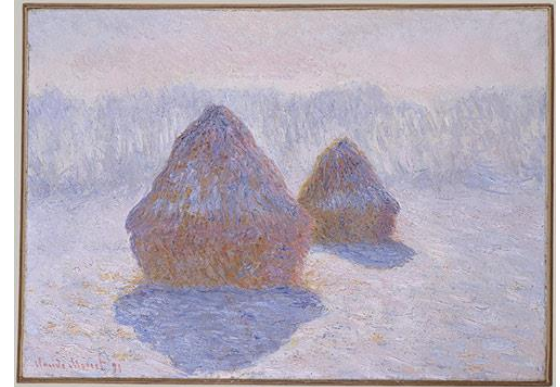
Full color tunable (RGB, RGBA, RGBAW, etc.)

Good things

- Matching other light sources in the room, even off black body
- Whiz-bang, eye-catching color effects. Signage and wayfinding
- Entertainment capabilities from a normally-white downlight: 4000K for daytime conference activities, change to 2500 K for an evening wedding or Hallowe'en cocktail party

Complications

- Requires at least 3 LED primaries and a more complex user interface than a simple slide dimmer. Luminaire powered separately from the dimmer/color control signal. DMX, DALI, or wireless control with high resolution required. Reprogramming may require a trained facility manager or in-house specialist.
- Difficult to completely match spectrum to another source with 4+ LED primaries. There are many recipes for creating “3000K” from an RGB+ source, but none of those R,G,B+ recipes will produce identical color rendering.
- RGBW permits almost infinite color selection, but some combinations can oversaturate (“cartoon-like”) or undersaturate (drab/greyed-out) colors.
- Efficacy of system is lower than fixed white LEDs.



Monet's haystacks, painted under different times of day, light conditions

Color Tunable and Tunable White Luminaires

Dim to Warm

Good things

- Needs at least three LED primaries to dim along the blackbody curve (e.g., from 1600 K to 3000 K) like incandescent.
- Some provide lovely buttery color at the bottom end of the dimming curve (not just amber). Virtually visually indistinguishable from incandescent.

Complications

- Sometimes you want to reduce light output without changing color. (A conference room is an example.) In those applications, it would be helpful to have separate dimming control from color change.
- Efficacy of system is lower than fixed white LEDs.



The Hurricane Club, Paul Gregory, LD

Color Tunable and Tunable White Luminaires

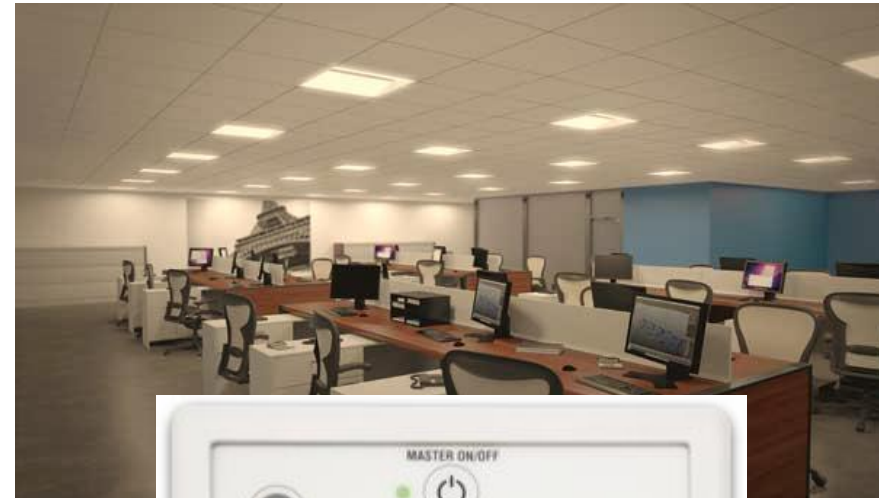
Tunable White

Good things

- Can be two sets of LED primaries, one warm and one cool. By fading from warm LEDs to cool LEDs with the intermediate CCTs created by mixing different levels of warm and cool LEDs, a range of colors *close* to the black body curve is possible.
- Separate power from control required (0-10V, DMX, DALI, wireless 2-channel). Having a slider for CCT change and another for intensity seems intuitive. User interface is the critical factor.
- Some products use 3 or more LED primaries.

Complications

- Some products use a separate control slider for the warm LED set and the cool LED set. Clumsier to get to desired color and output.
- Wiring may be more complex.
- Efficacy of system may be similar to fixed white LEDs.



Finelite color controller

Color Tunable and Tunable White Luminaires

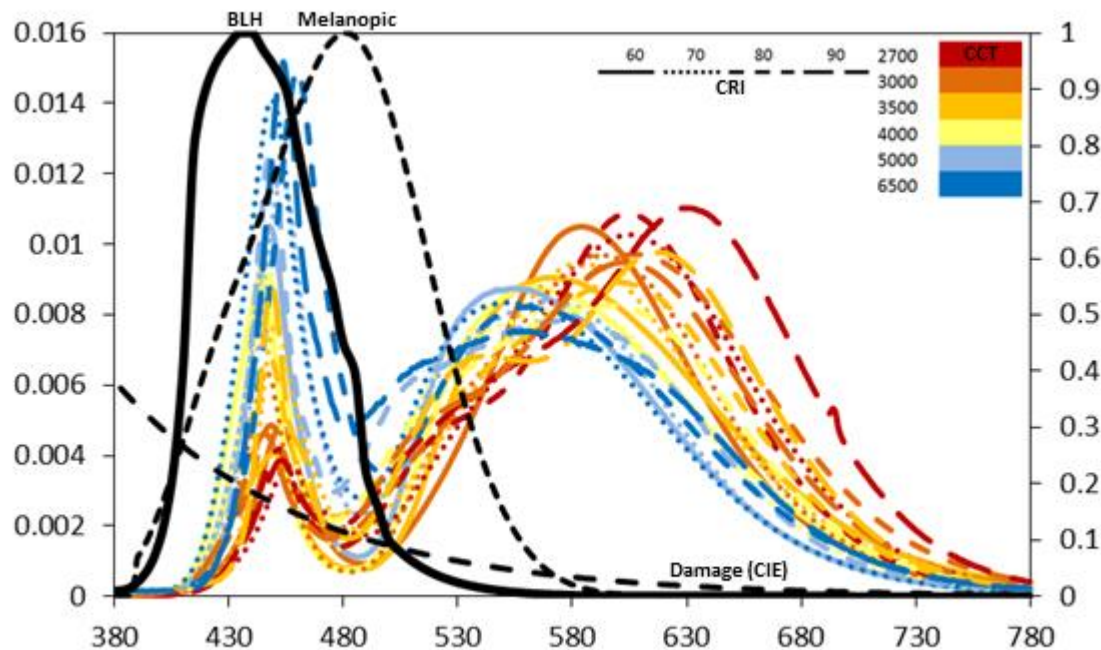
Product ID	Input Power (W)	Output (lm)	Efficacy (lm/w)	CCT (K)	R_f	CRI R_a
15-01 2x2 troffer, linear tuning, 2 LED primaries	18.1 – 23.5	2,153 – 2,832	110 – 122	3094 – 6696	83 – 85	84 – 87
15-07 downlight, linear tuning, 2 LED primaries	15.2 – 15.3	735 – 891	48 – 59	2188 – 5691	80 – 84	79 – 86
15-10 round ceiling light, linear tuning, 2 LED primaries	47.9 – 51.8	5,457 – 5,931	108 – 124	2742 – 6749	82 – 84	81 – 86
15-11 2x2 troffer, linear tuning, 2 LED primaries	39.2 – 41.6	4,028 – 4,588	100 – 114	2722 – 6188	81 – 84	82 – 86
15-02 downlight, blackbody tuning, 4 LED primaries	16.8 – 26.1	476 – 843	28 – 32	2590 – 5576	86 – 92	89 – 96
15-05 downlight, blackbody tuning, 5 LED primaries	12.2 – 28.1	263 – 905	22 – 32	1628 – 3833	86 – 94	92 – 98
15-08 downlight, blackbody tuning, 4 LED primaries	21.3 – 24.2	687 – 692	28 – 32	2671 – 6359	83 – 90	82 – 92
15-09 downlight, 3 LED primaries	16.6 – 19.0	703 – 868	38 – 47	2017 – 4437	81 – 88	83 – 91

Results from DOE CALiPER Testing, **Report 23: Photometric Testing of White-Tunable LED Luminaires, August 2015**

Color Tunable and Tunable White Luminaires

Health benefits?

- It's too early to know what the benefits/hazards are for most applications. The effect of polychromatic light is still in research.
- The size of the effect compared to static lighting is unclear
- Individual physiology, light history, age, health, will affect the light prescription



Variation in SPD of 15 different LEDs from CALiPER testing

- 2700K – 6500K, range of CRIs
- Compared here to one circadian response function (“melanopic”)
- Changing from 2700K to 6500K increases melanopic lumens by 2.5 and vice versa

Color Tunable and Tunable White Luminaires



How to design for health? An example of the difficulty: Lighting for Neonatal unit

- Design to lux or circadian lux? What model?
- Design at multiple times of day?
- Who gets control of lighting/programming?
- Design for mom and baby, or nurses?
- How does light spectrum affect tissue color evaluation? (Cyanosis, jaundice, redness)
- How do you know if it's working?

WE DON'T KNOW.

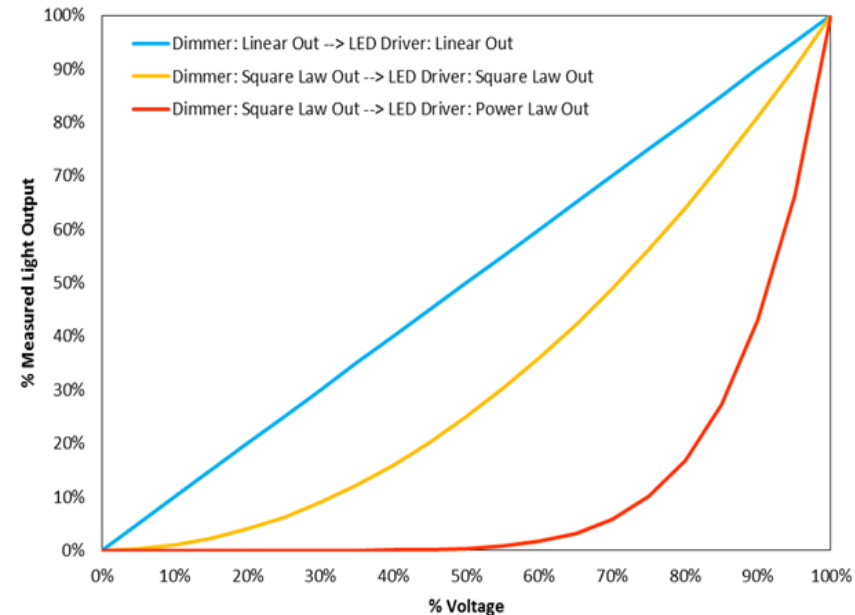
NEED more RESEARCH.



Color Tunable and Tunable White Luminaires

Dimming issues

- User interface and intuitiveness of control
- Smoothness of dimming and color change
- Resolution of dimming
- How fast the luminaire reacts to dimming signal
- How low does it go?
- How does it transition to OFF?
- How does it transition from OFF to low levels?
- Dimming curves
- Flicker from system
- Complexity of programming system for owner
- Wiring requirements, construction issues, cost
- Software needed, hack resistance
- Protocol translators
- How color-change controls play with others in room



Color Tunable and Tunable White Luminaires

What information do you need on the product spec sheet?

- Full color tunable (RGB etc.), Dim-to-warm, Tunable White Light
 - SPD and photopic lumen output at highest CCT, lowest CCT, and in between *at the very least (5 to 7 points much more precise)*
 - Maximum and minimum watts drawn at max, min, mid CCTs
 - Candela curve for distribution info
 - Controls protocol (0-10V, DMX, DALI; wired vs. wireless)
 - Compatible controls, and any interfaces between controls and driver
 - Cable type and connectors among control, interface, & luminaire
 - Driver type, logarithmic or linear dimming curve
 - Minimum dimming level, whether it dims to off
 - % Flicker and Flicker Frequency at max, min, and mid output level
 - Max and min number of luminaires on controller
 - How to order the COMPLETE system
-
- And, perhaps, maximum melanopic lumens at high CCT, low CCT, mid CCT? Is there an accepted standard?

Color Tunable and Tunable White Luminaires

Energy Savings??

- Compared to incandescent....
Yes.
- Compared to highest efficacy LED commercial products.....
Sometimes.
- Complication: The energy codes don't know how to deal with these products.



Image courtesy Finelite Lighting