

Dim-To-Warm LEDs – Opportunities and Challenges

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Color Tuning Basics : Product Categories

- Dim-To-Warm products – Discussed Today
 - Single channel device
 - Fixed dimming curve linking flux and CCT
 - Mimic incandescent or halogen dimming characteristics
- Color tunable products – NOT Discussed Today
 - 2 or more independent channels
 - White light on or near black body locus (BBL) or RGB(W) tuning
 - Independent control of flux and CIE coordinates
 - Can also be used to achieve dim warm effects



Dim-To-Warm Products : Objectives

- Primary objective: Mimic incandescent/halogen dimming in a high efficiency LED product
 - Creates familiarity with older technology
 - May accelerate LED adoption if fixed CCT dimming is deemed undesirable
- Usage
 - Residential and hospitality
 - Create a warm ambience for evening activities



Dim-To-Warm Products : Market Adoption

- Market adoption for these products is rapidly increasing
 - Used with standard dimmable LED drivers
 - No controls system required
 - Retrofit of existing fixtures to dim-warm capability is relatively easy
 - Price premium over fixed white general illumination is small
- Several COB and SMD options already exist on the market
 - Many component manufacturers are entering this space
 - Halogen-like dimming is targeted; efficacy requirement is modest
 - Manufacturing using new technology platforms is cost prohibitive
- Many ecosystem solutions already in the market
 - Electromechanical holders
 - Optics

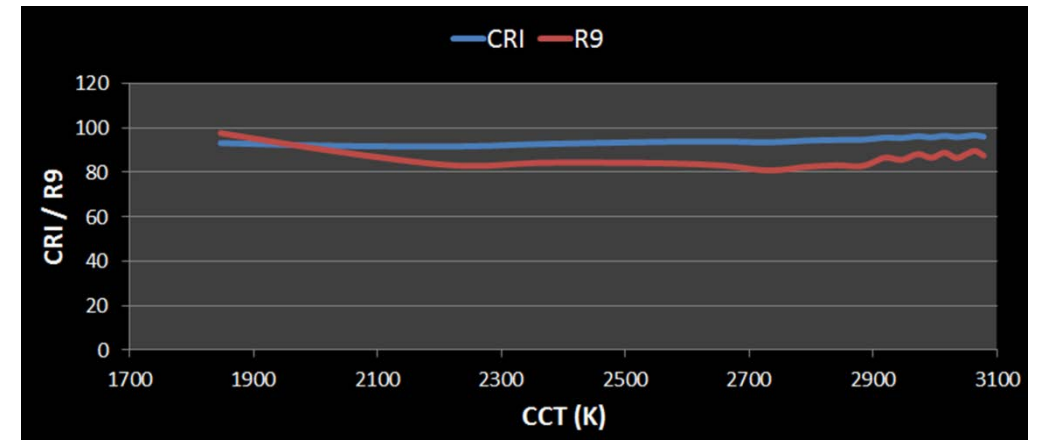
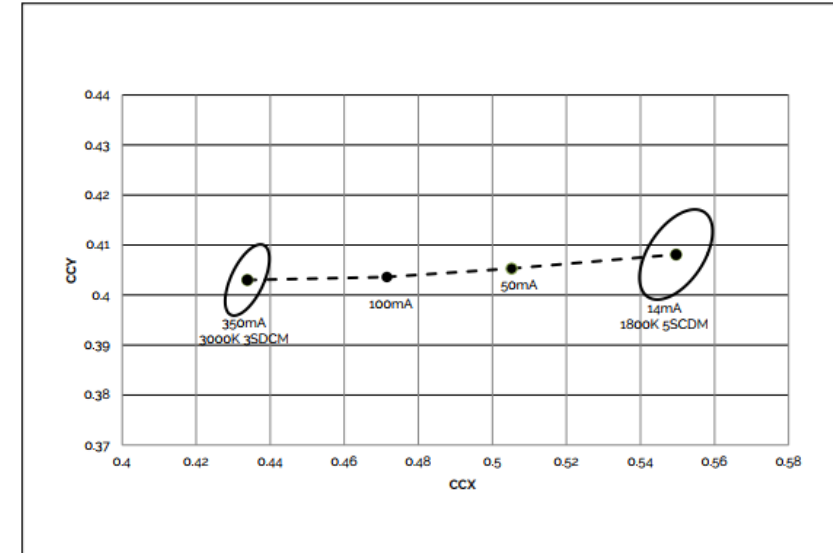


Collingwood Lighting

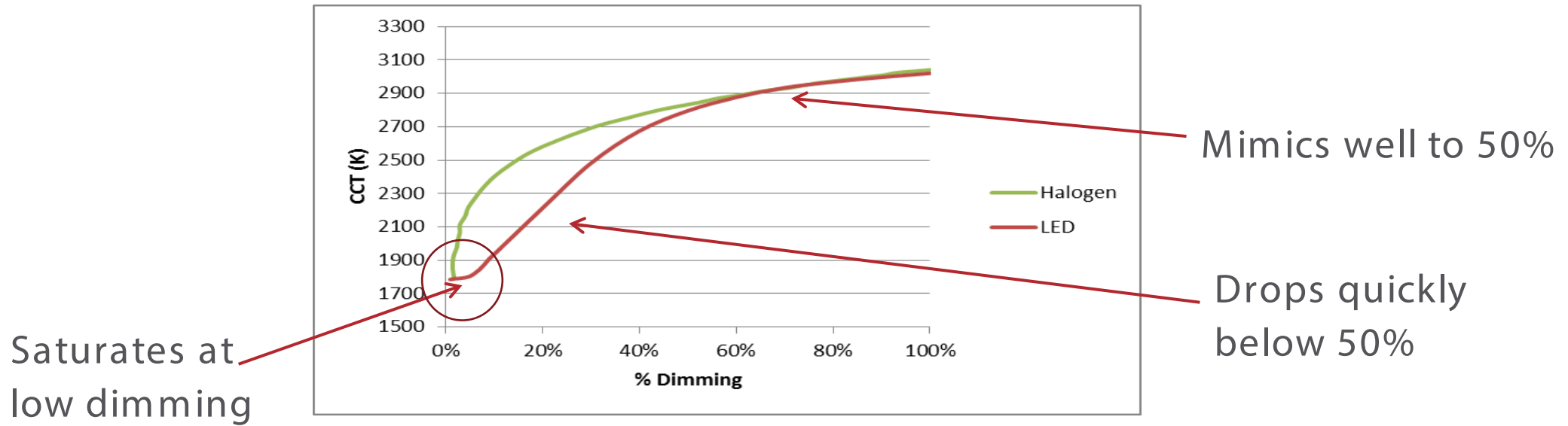


Dim-To-Warm Products : Color Quality

- CCT / CRI
 - To best mimic halogen or incandescent
 - $R_a \geq 95$
 - $R_9 \geq 90$
 - High CCT = 2700K – 3000K
 - Low CCT = 1700K – 2000K
- Variation of color quality metrics should be minimized across the dimming range
- Color binning can be a challenge compared to fixed white products, particularly at low dimming levels
- Options are generally more limited when choosing mid-power SMD components



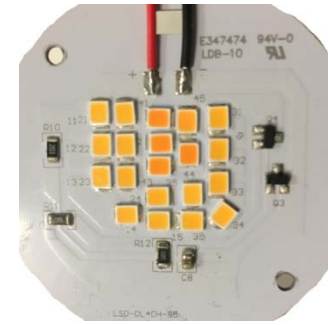
Dim-To-Warm Products : Dimming Performance



- Halogen or incandescent sources continue to reduce CCT throughout the dimming curve
- LED sources mimic well to 50% dimming, but then CCT drops rapidly
- LED sources saturate at low CCT; this should be restricted to <5% dimming

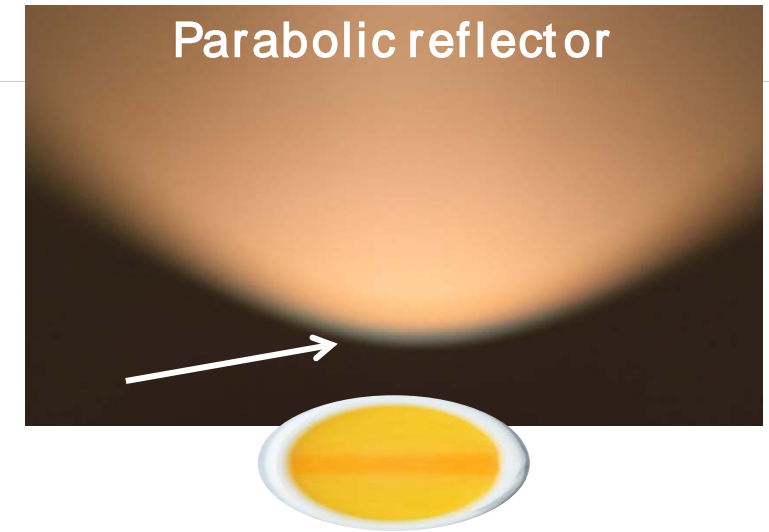
Dim-To-Warm Products : Dimming Control

- Dimming control is typically achieved using passive electronic components that shunt current to warm CCT strings at low dimming levels
- For most solutions, PWM dimming cannot be used
 - Delivered current must decrease when dimming in order to achieve CCT changing effect



Dim-To-Warm Products : Optic Requirements

- Omnidirectional and wide beam applications (larger downlights, etc.)
 - Mid-power SMD modules are generally acceptable and most economical
- Narrow beam applications (tracks, spots, etc.)
 - COB products are generally a better solution
 - Color angular uniformity can be an issue with some COB solutions due to phosphor patterning
 - With “weak” optics, color uniformity suffers off axis
 - Color uniformity is also dependent on the orientation of the array
 - Many optics available to improve color uniformity
 - CSP solutions can provide better color uniformity, but come at a higher cost and typically lower efficacy



Dim-To-Warm Products : Is This a Good Thing?

- Compared to fixed white LED lighting, dim-to-warm products generally have lower efficacy
- Is it better to force people to accept dimming with a fixed CCT?
- Or should the industry cater to preferences built on old, inefficient lighting technology?
- Is it already too late???

Conclusions

- Dim-to-warm LED options are gaining popularity
 - Largest market is still Northern Europe, but US is expanding
 - “Entry-level” CCT tuning
- Applications are currently restricted to residential and hospitality markets
- When specifying products, color quality metrics and dimming performance should be carefully considered
- Color uniformity needs to be managed properly when using COBs for narrow beam applications



Thank You