

IES TM-30-15: Learn the Basics, See the Results

DOE Workshop

November 17, 2015

Michael Royer, PNNL

CIE CRI (1965/1974)

IES TM-30-15 (2015)

CIE 1964 $U^*V^*W^*$

8 color samples

Medium chroma/lightness

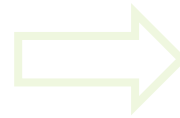
Spectral sensitivity varies

Munsell samples only

Reference Illuminant CIE Illuminant 2

No lower limit for scores
and inconsistent scales

Fidelity Metric Only



CAM02-UCS (CIE CAM02)

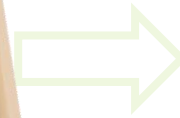


99 color samples

Uniform color space coverage

Spectral sensitivity neutral

Variety of real objects

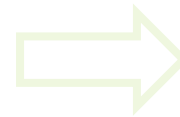


Ref Illuminant Continuous

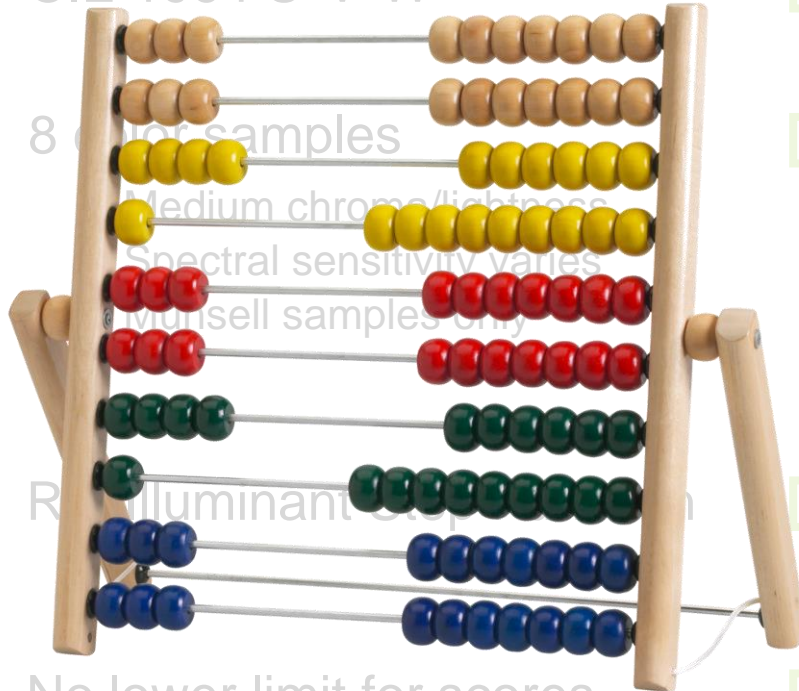
(Uses same reference sources, but blended
between 4500 K and 5500 K)



0 to 100 scale (fidelity)



Fidelity, Gamut, Graphical,
Detailed



CIE CRI (1965/1974)

IES TM-30-15 (2015)

CIE 1964 $U^*V^*W^*$

8

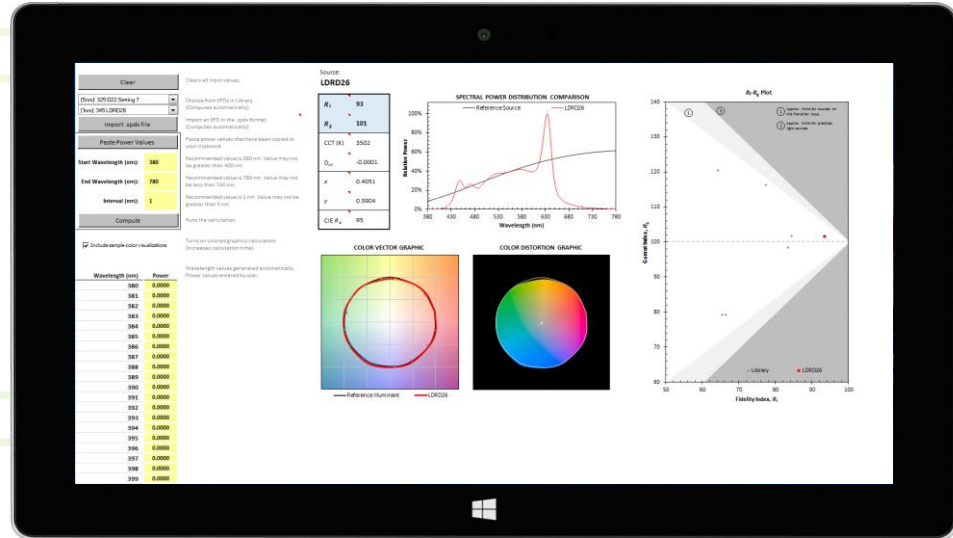


No lower limit for scores and inconsistent scales

Fidelity Metric Only



CAM02-UCS (CIE CAM02)



0 to 100 scale (fidelity)



Fidelity, Gamut, Graphical, Detailed

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Medium chroma/lightness
Spectral sensitivity varies
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Ref Illuminant Step Function

No lower limit for scores
and inconsistent scales

Fidelity Metric Only

IES TM-30-15 (2015)

CAM02-UCS (CIE CAM02)

99 color samples

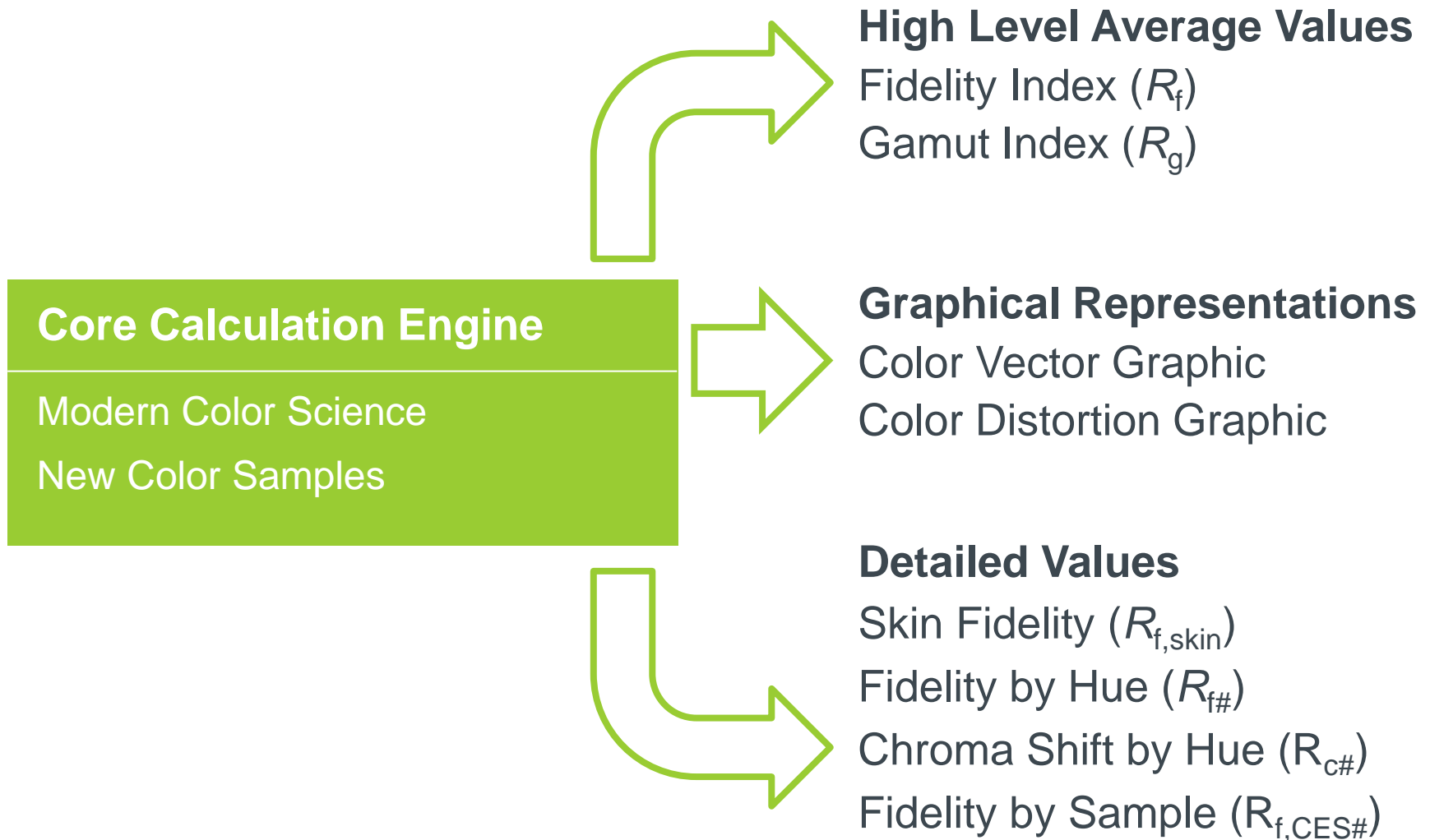
Uniform color space coverage
Spectral sensitivity neutral
Variety of real objects

Ref Illuminant Continuous

(Uses same reference sources, but blended
between 4500 K and 5500 K)

0 to 100 scale (fidelity)

Fidelity, Gamut, Graphical,
Detailed



IES TM-30-15 Method

Color Fidelity

The accurate rendition of color so that they appear as they would under familiar (reference) illuminants

Fidelity Index (R_f)
(0-100)

Color Gamut

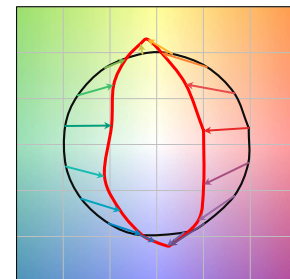
The average level of saturation relative to familiar (reference) illuminants.

Gamut Index (R_g)
~60-140 when $R_f > 60$

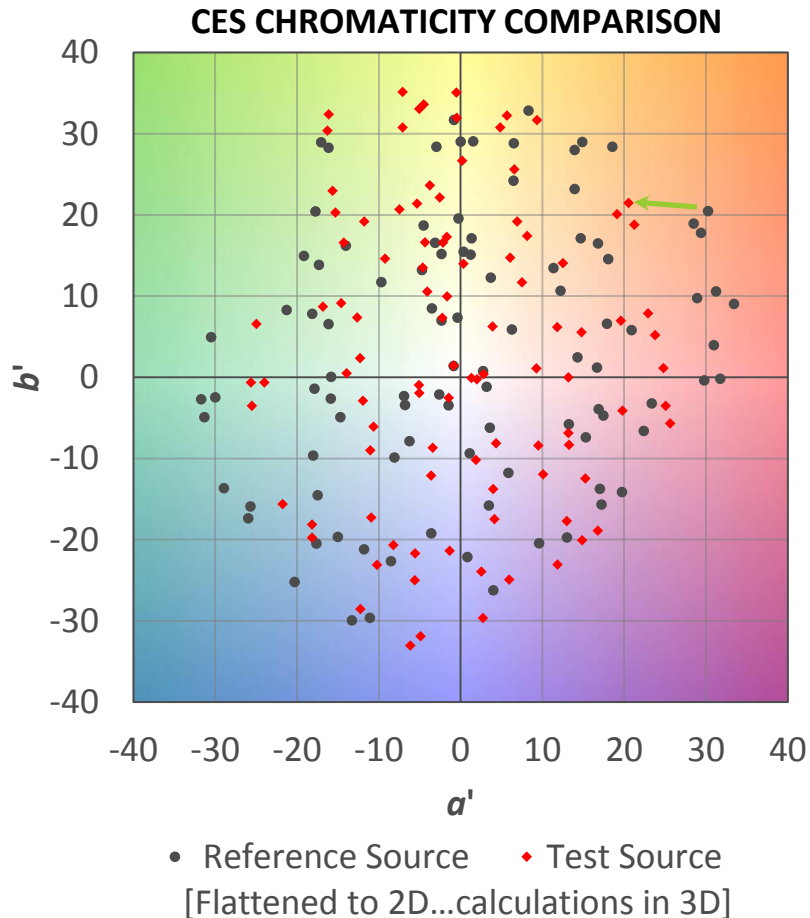
Graphics

Visual documentation of hue and saturation changes.

Color Vector Graphic

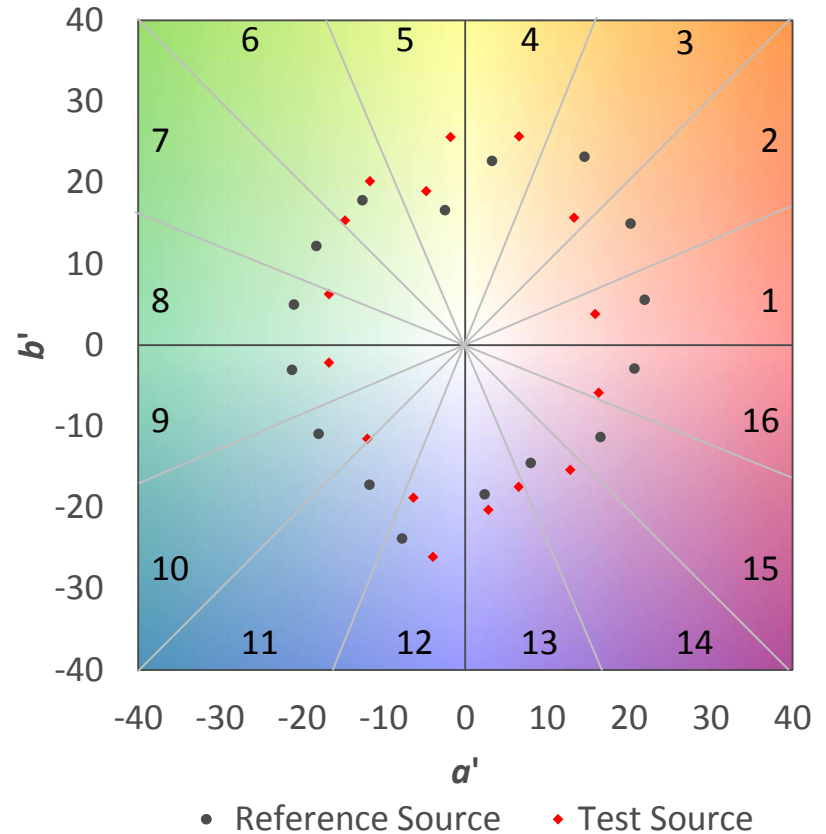
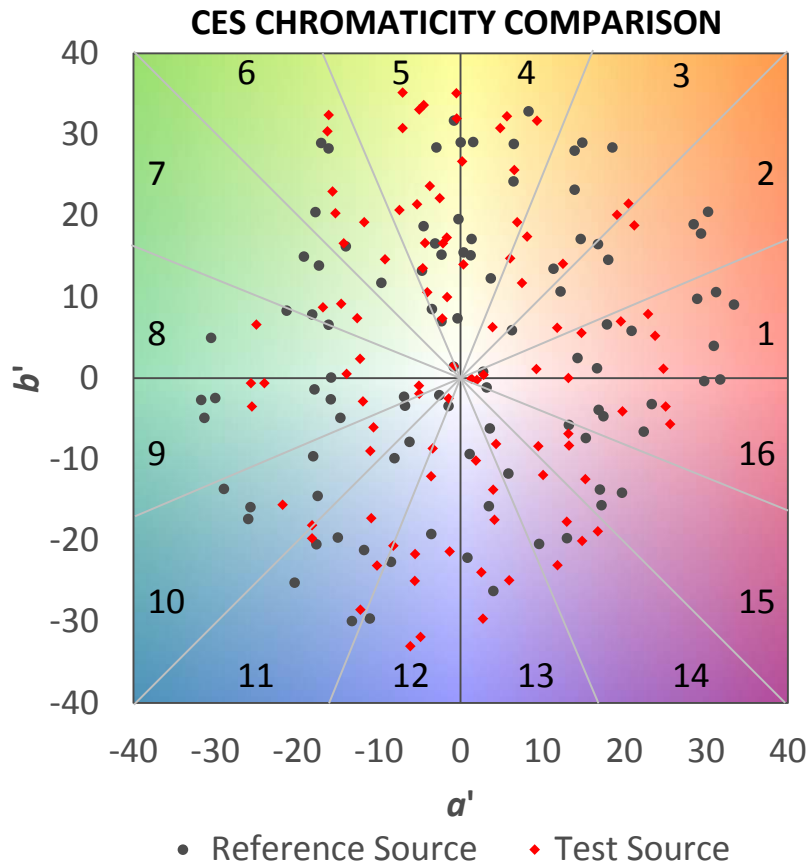


TM-30-15 (Average) Fidelity



1. Calculate chromaticity of 99 CES with test source and reference illuminant using CAM02-UCS.
2. Calculate color difference for each pair of color coordinates.
3. Average Differences.
4. Scale Value.
5. Subtract from 100.
6. Adjust scores less than zero.

TM-30-15 Hue Bins



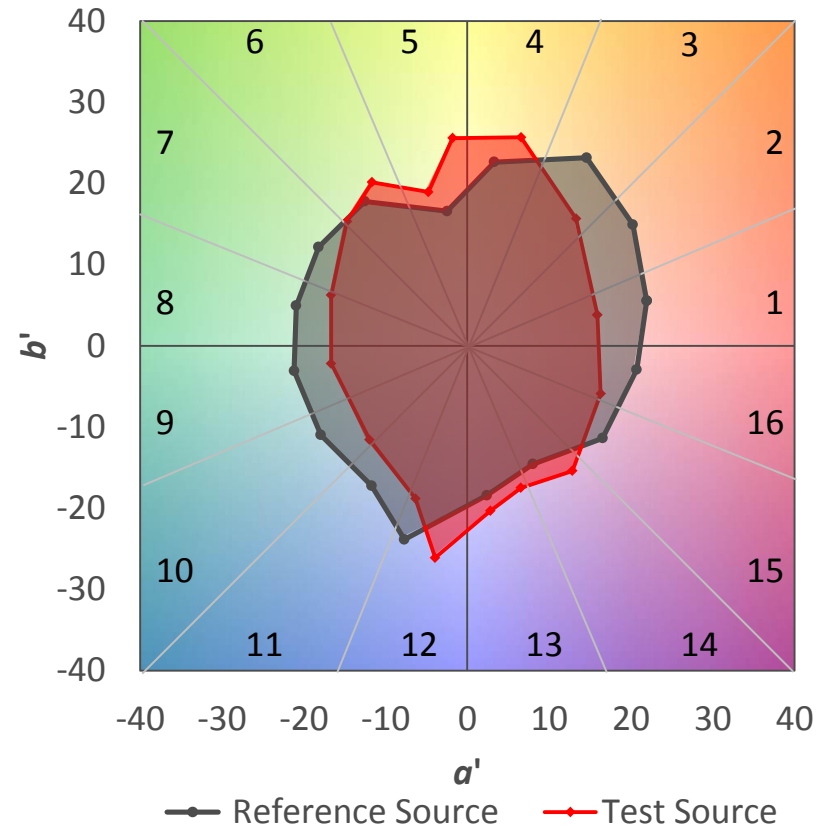
Average (a' , b') chromaticity coordinates in each bin (binned by reference condition).

TM-30-15 Relative (Average) Gamut

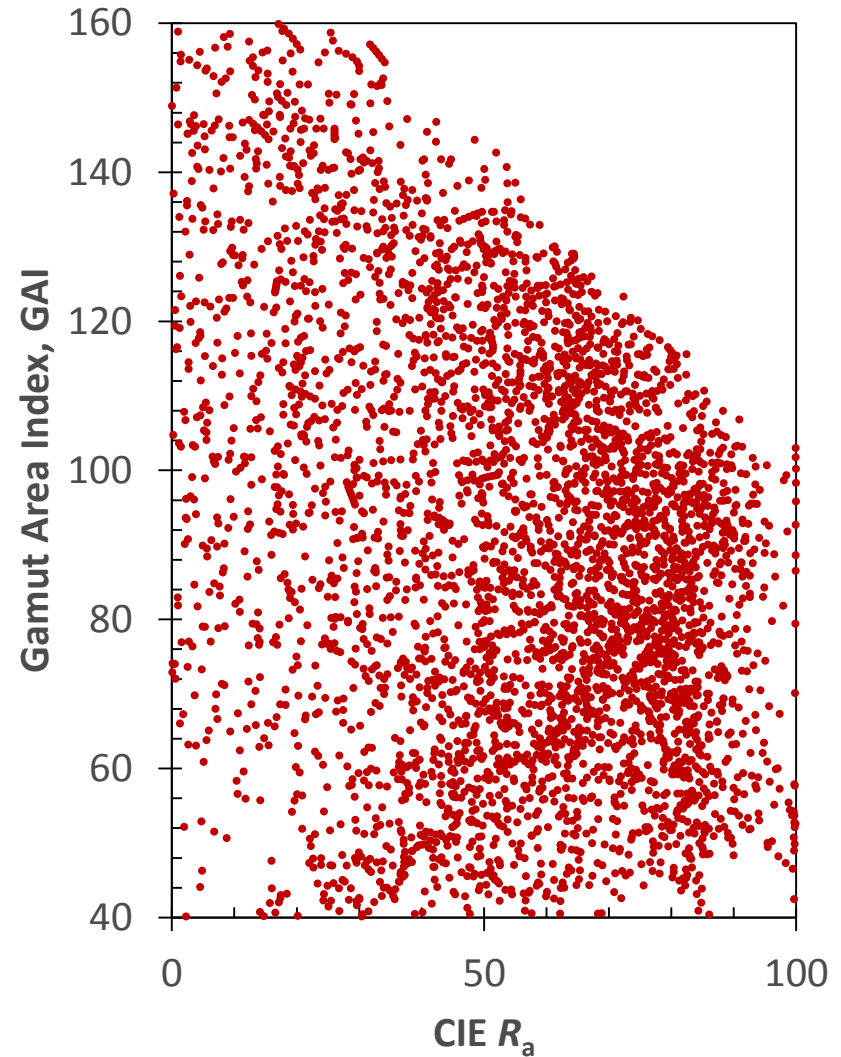
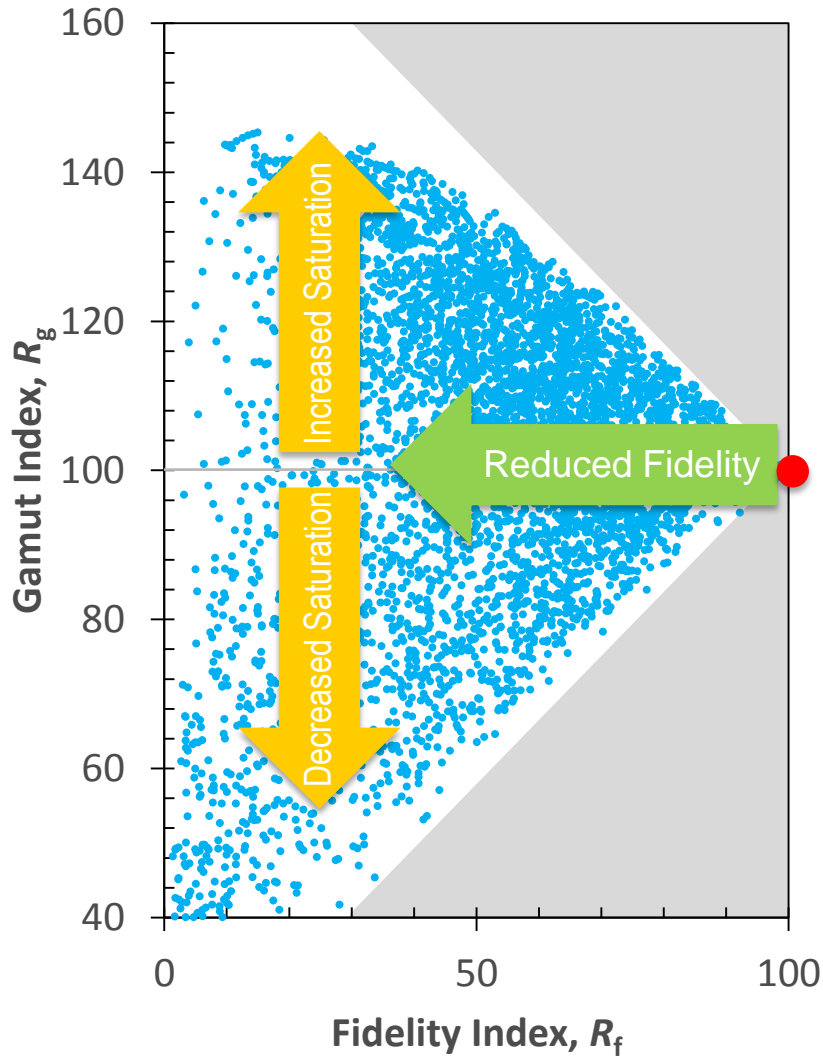
$$R_g = 100 \times \frac{A_t}{A_r}$$

$R_g > 100$: Average increase in saturation

$R_g < 100$: Average decrease in saturation

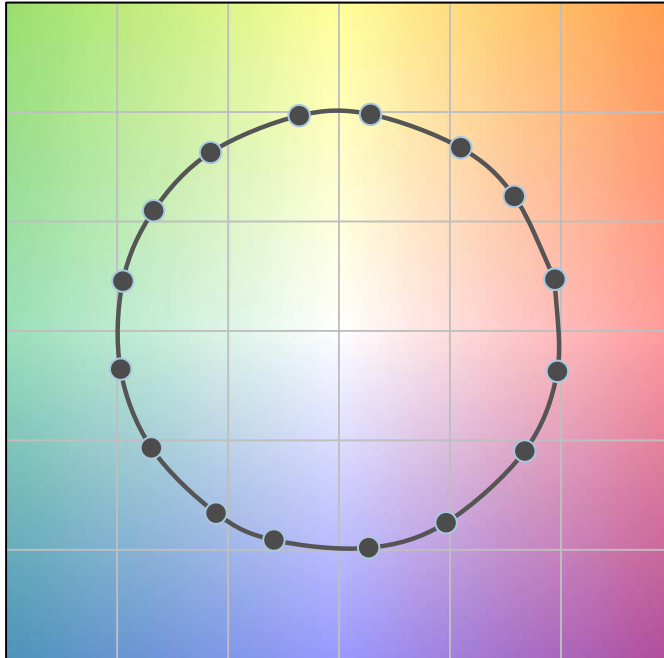


A Cohesive Two-Axis System

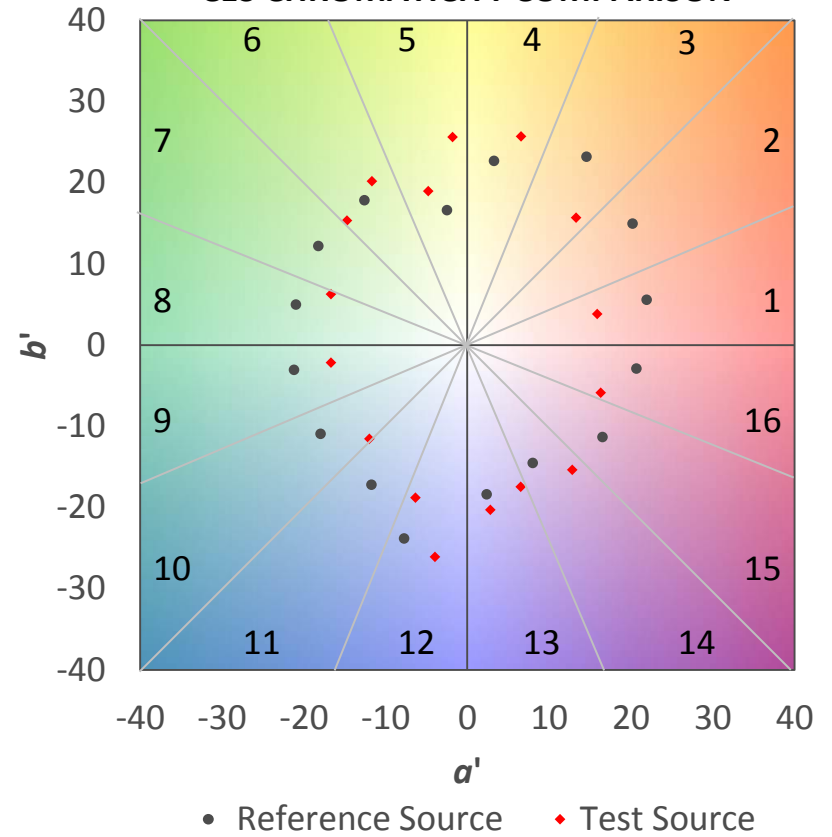


TM-30-15 Vector Graphics

COLOR VECTOR GRAPHIC

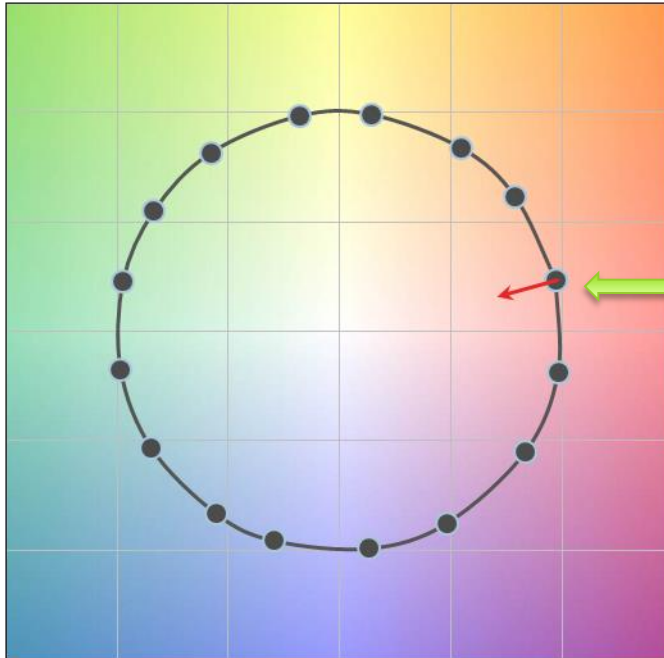


CES CHROMATICITY COMPARISON

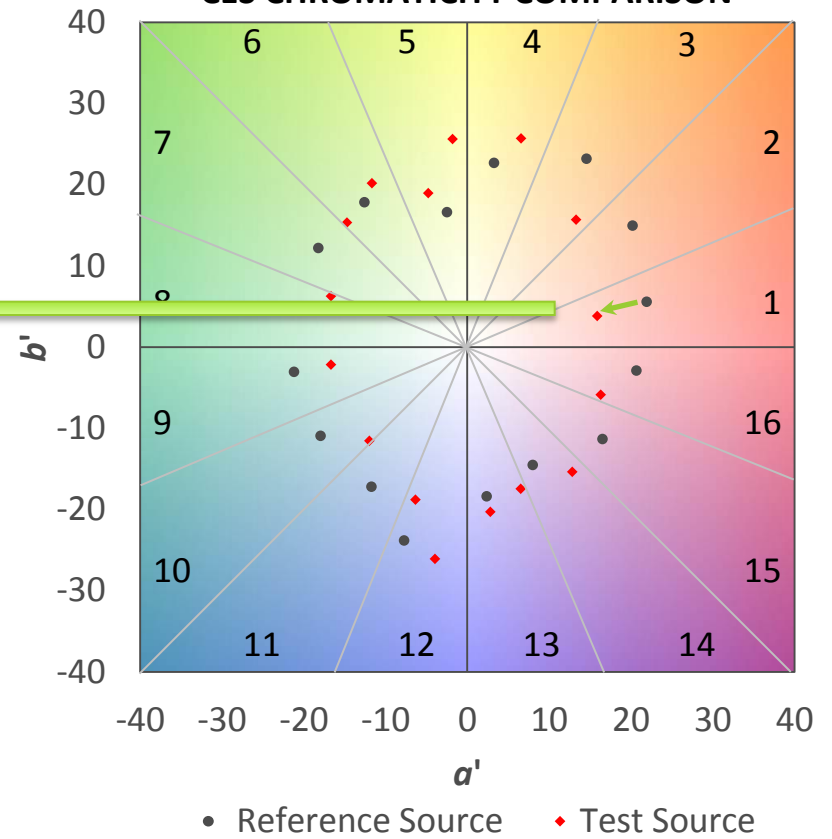


TM-30-15 Vector Graphics

COLOR VECTOR GRAPHIC

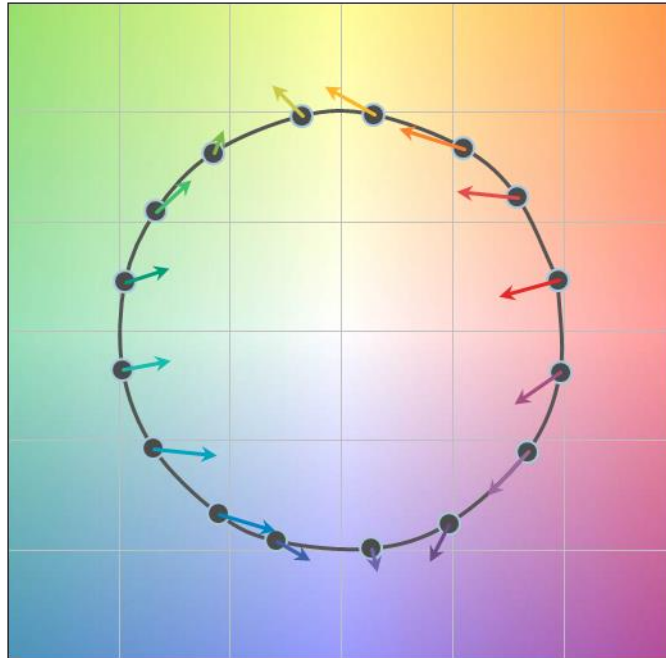


CES CHROMATICITY COMPARISON

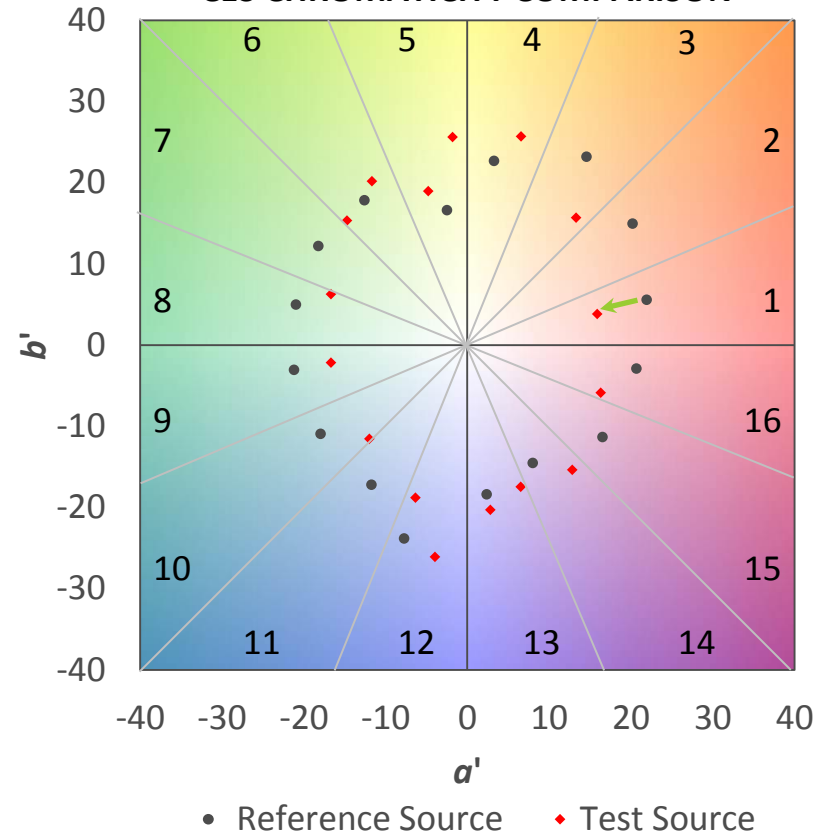


TM-30-15 Vector Graphics

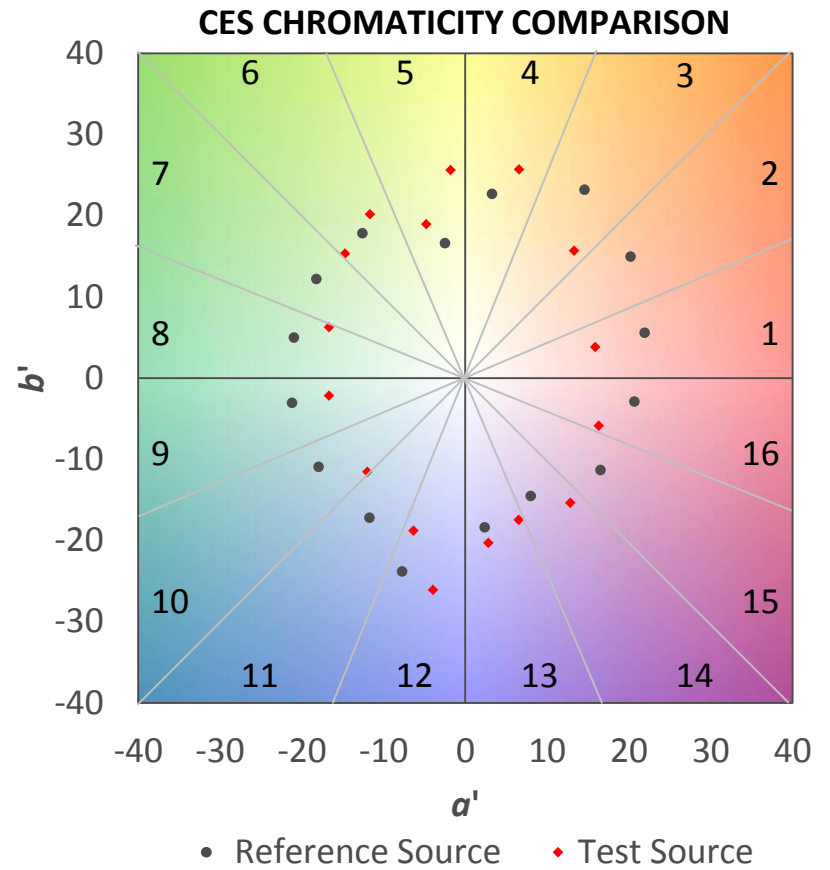
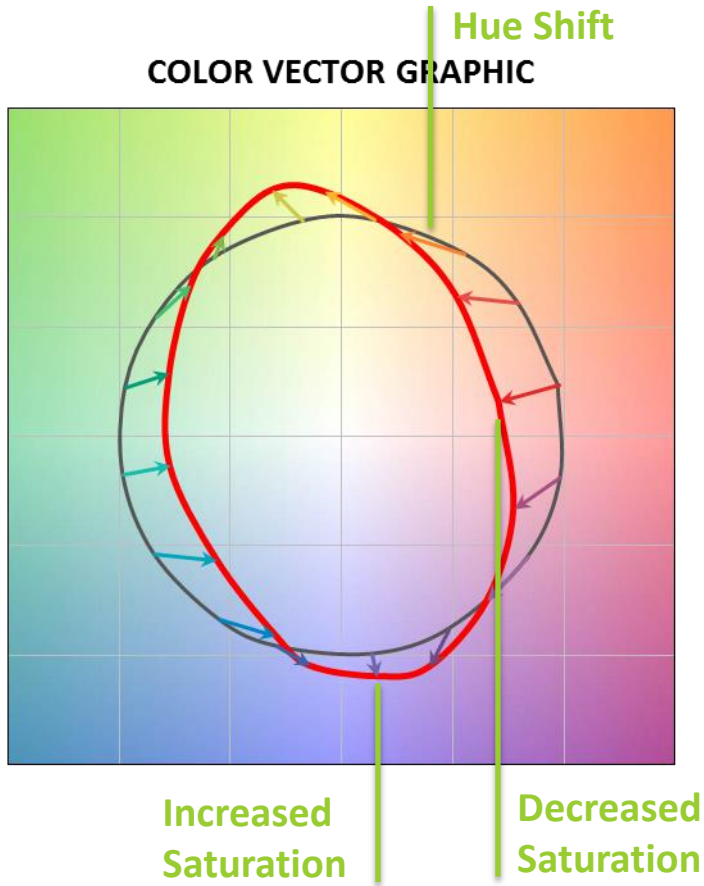
COLOR VECTOR GRAPHIC



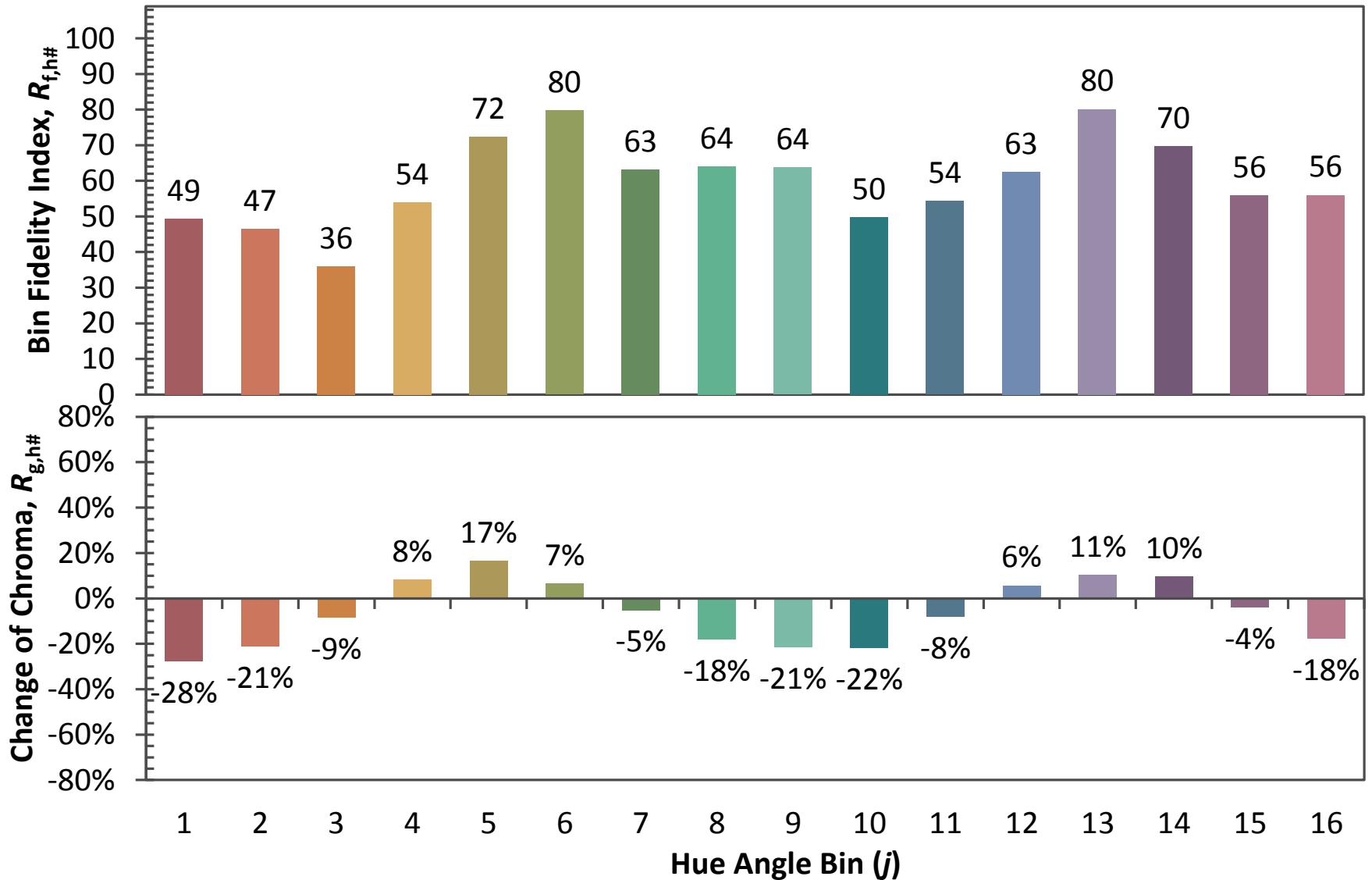
CES CHROMATICITY COMPARISON

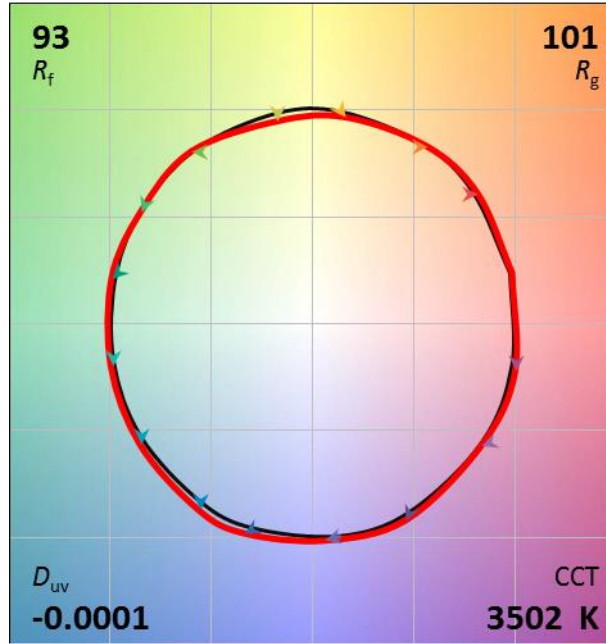
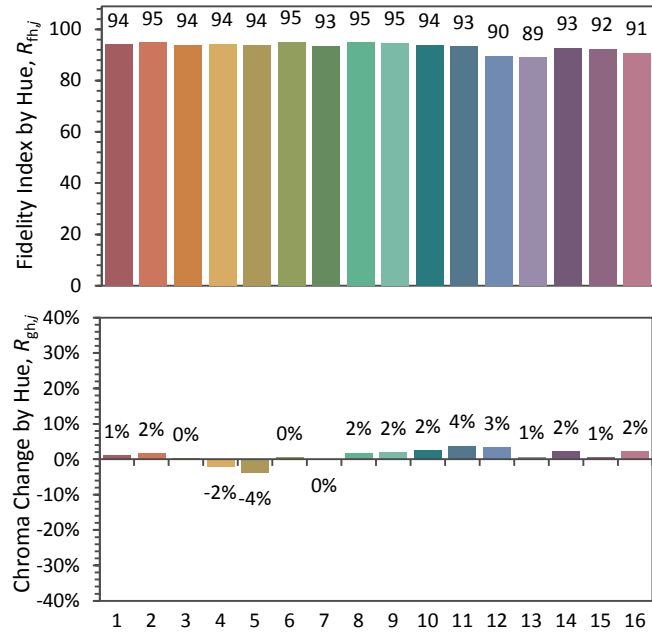
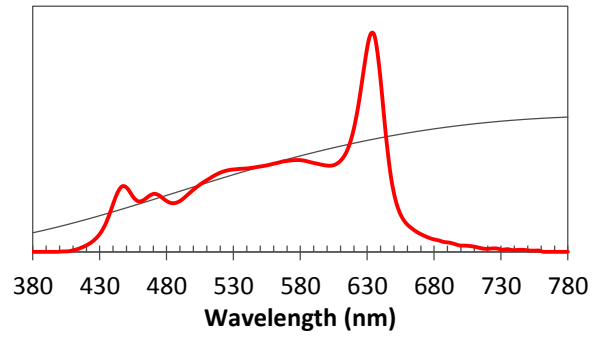


TM-30-15 Vector Graphics



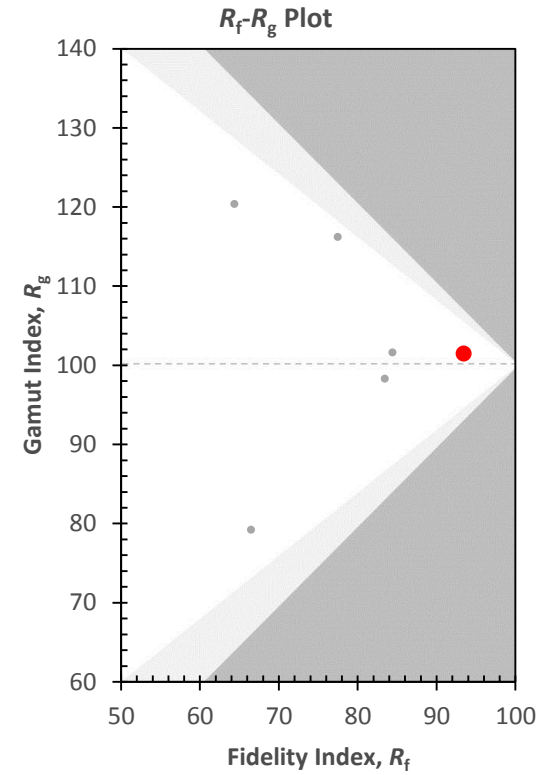
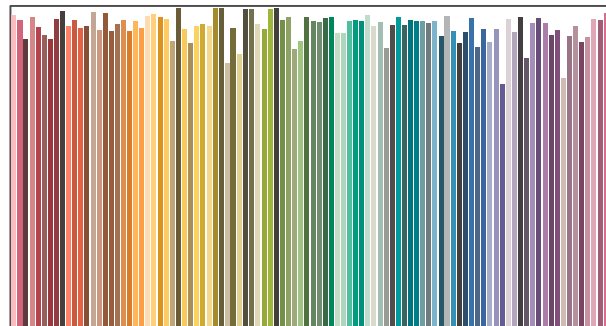
TM-30-15 Hue Bin Indices

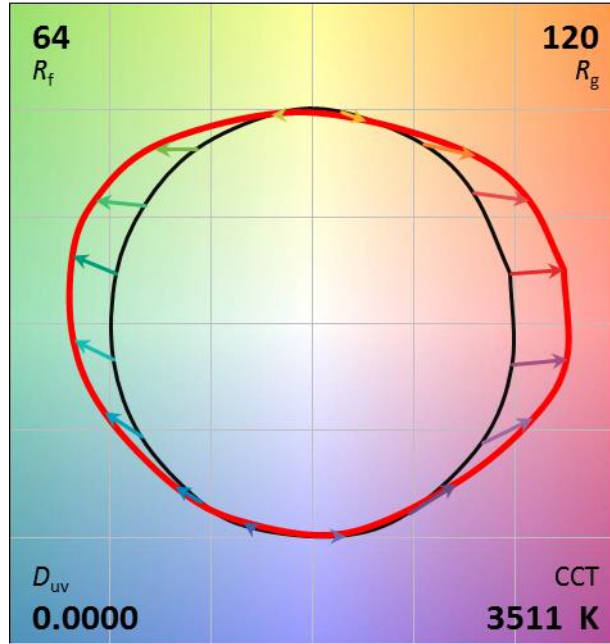
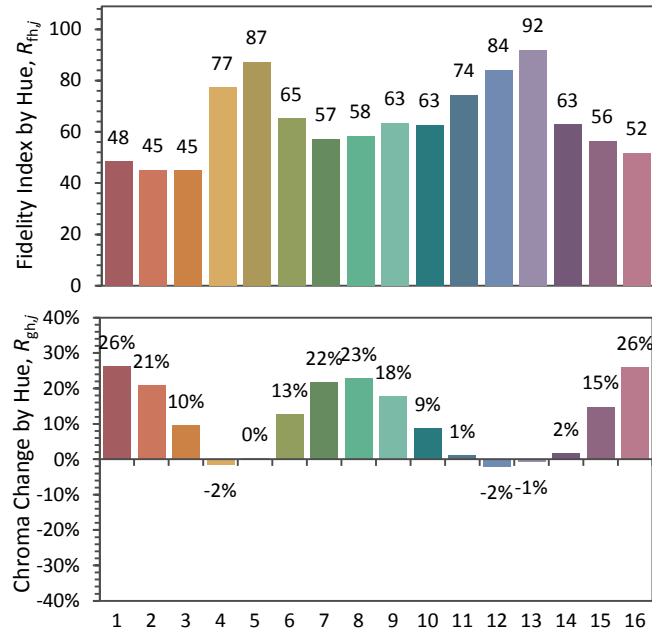
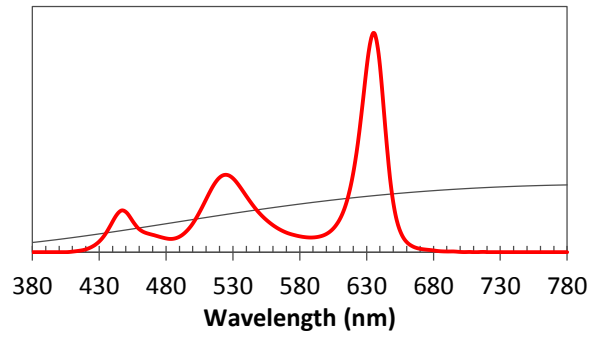




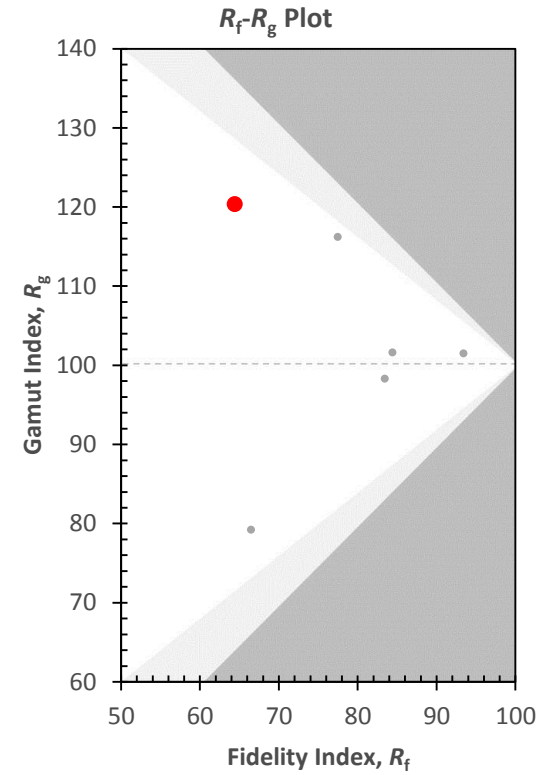
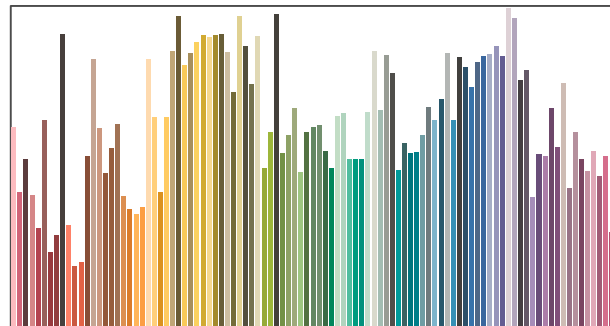
CRI R_a : 95, R_g : 80

LER: 321

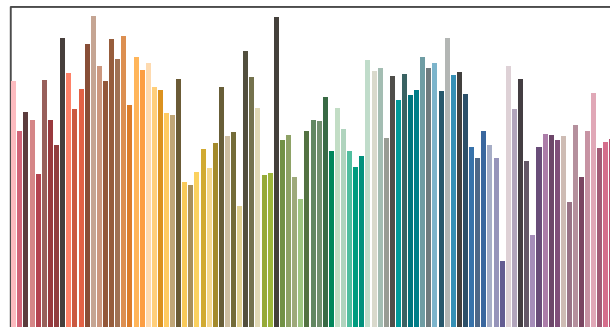
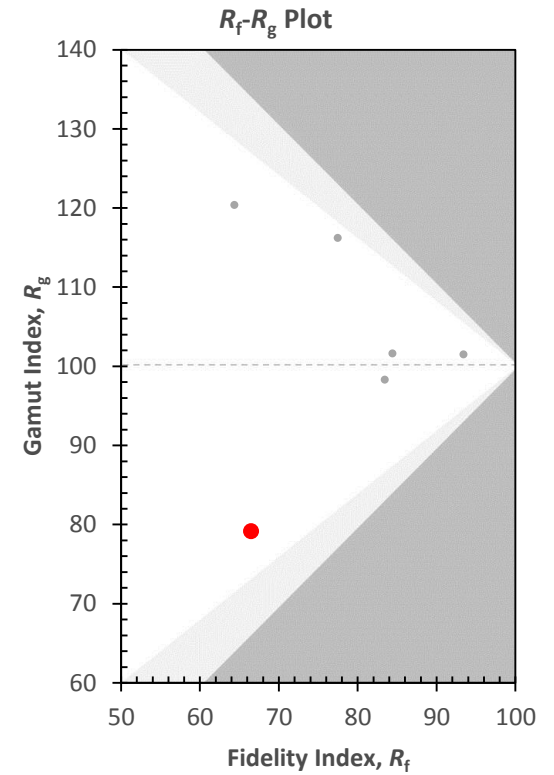
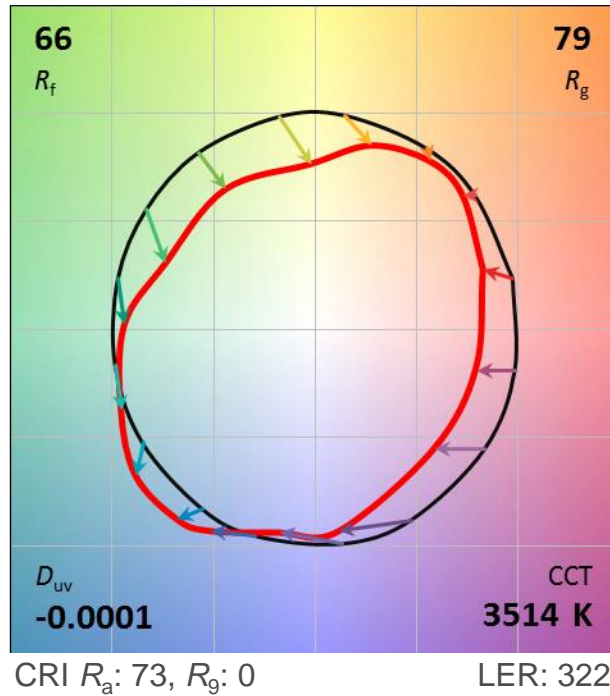
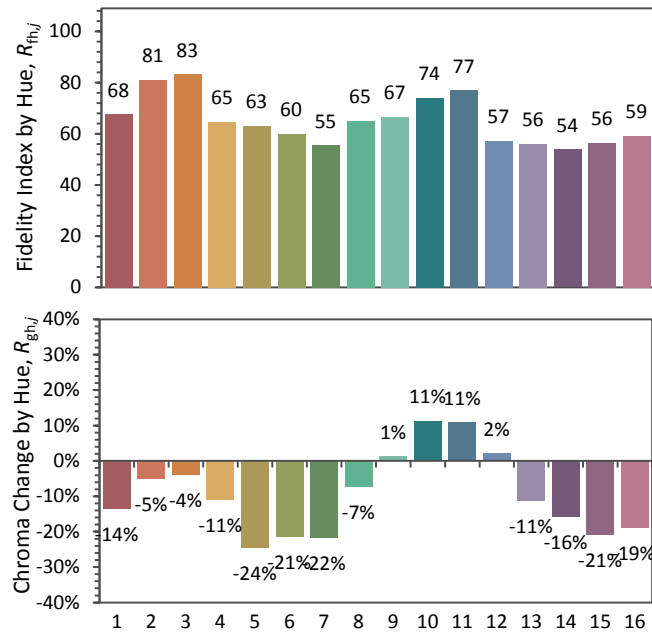
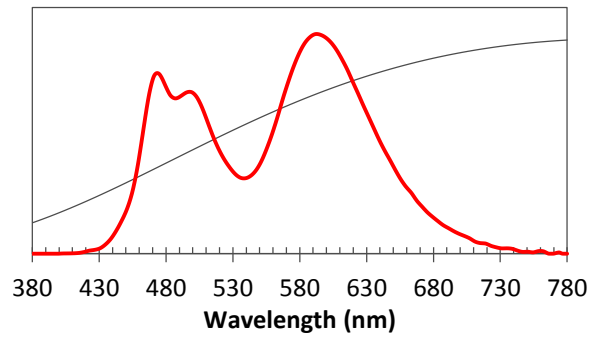




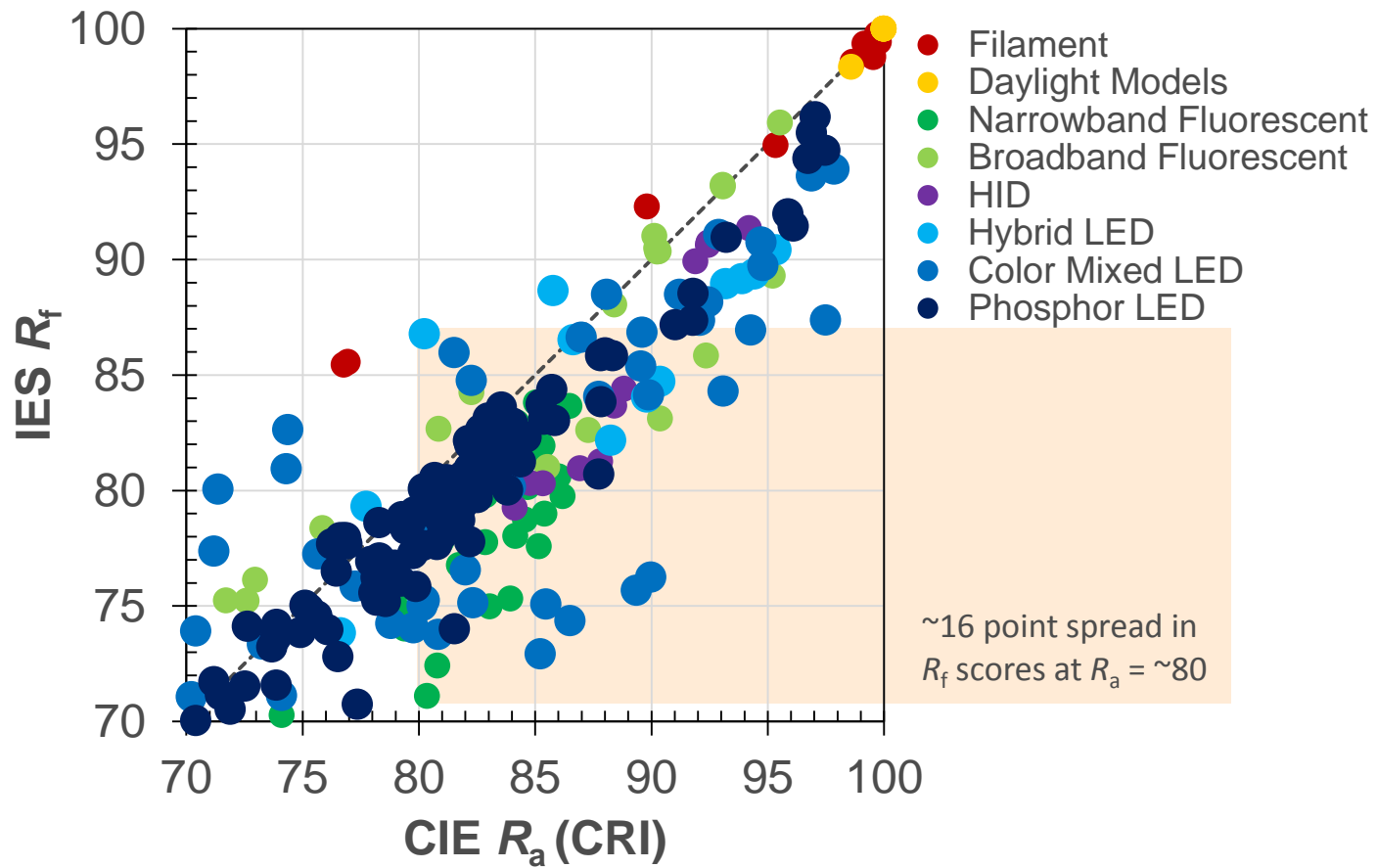
CRI R_a : 43, R_g : -120 LER: 287



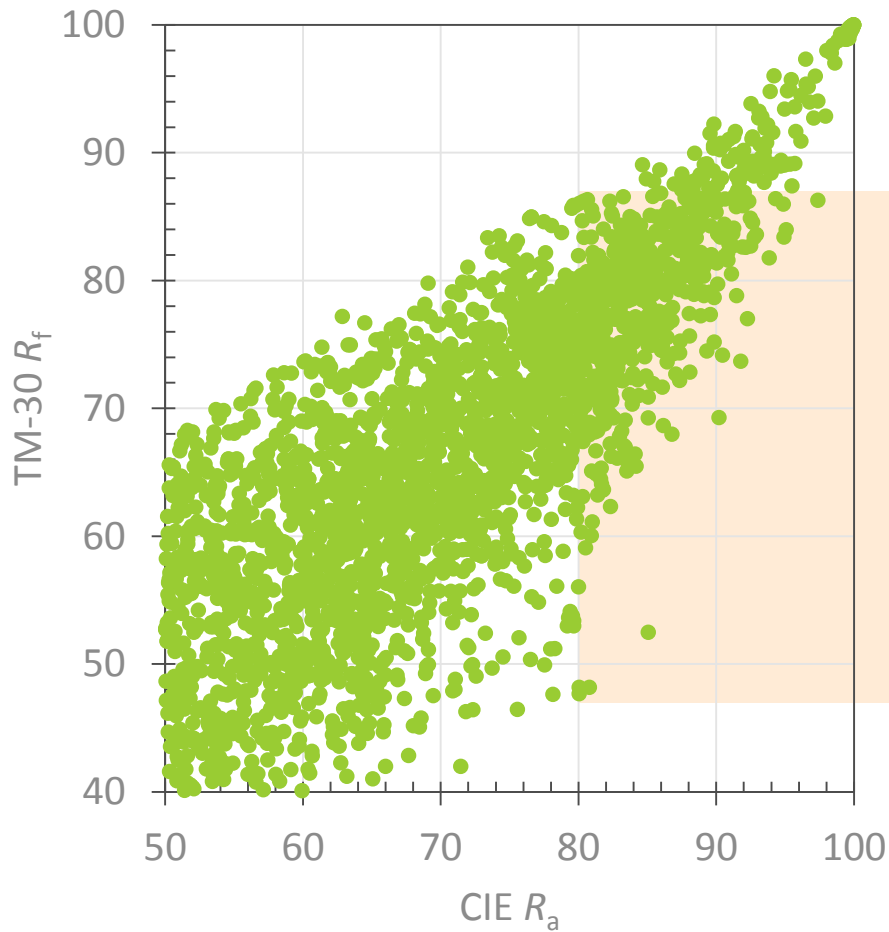
1



CIE CRI R_a vs. IES TM-30 R_f



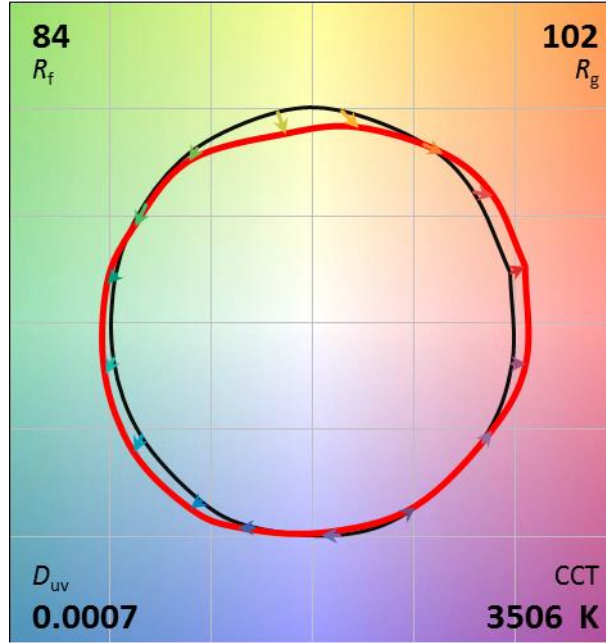
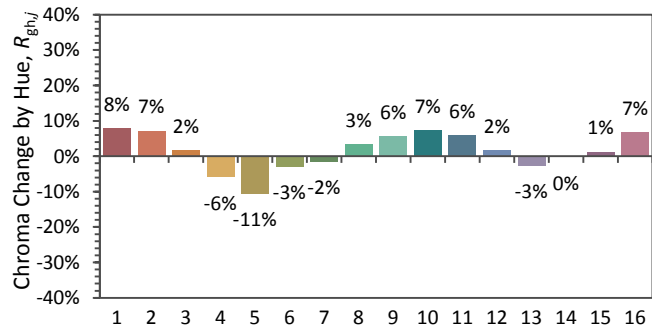
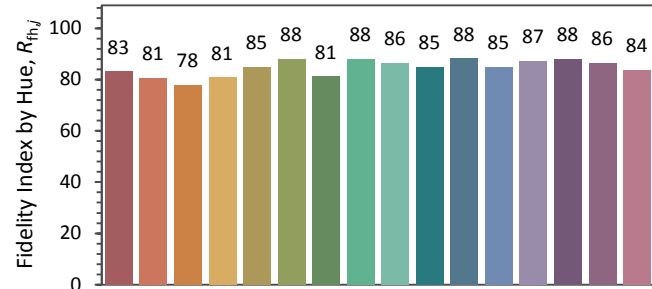
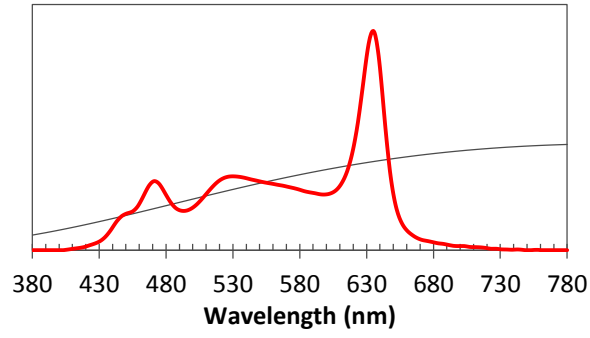
CIE CRI R_a vs. IES TM-30 R_f



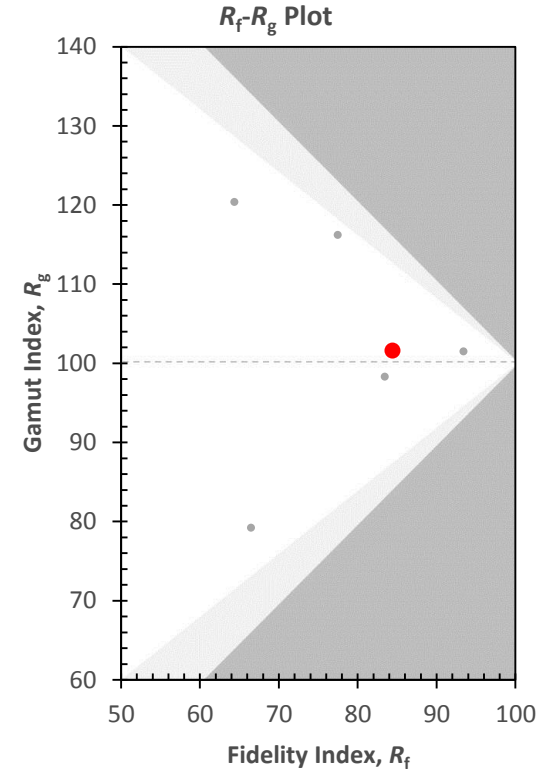
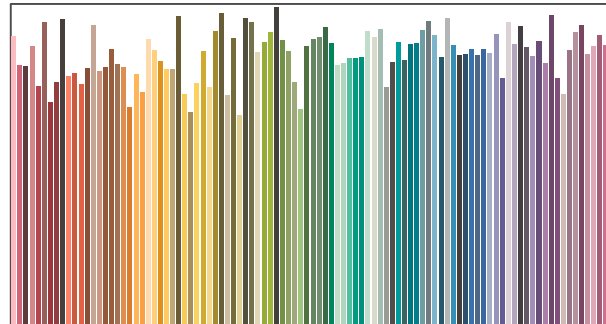
49 point spread
(error) in fidelity
score at CRI of 80.

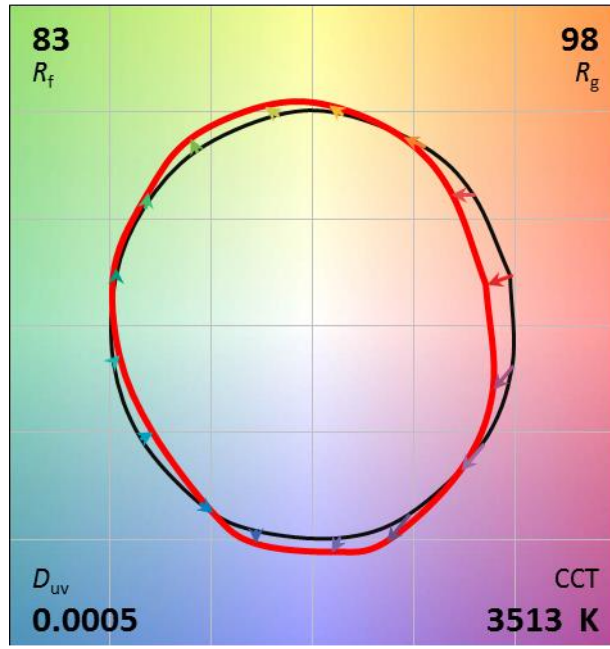
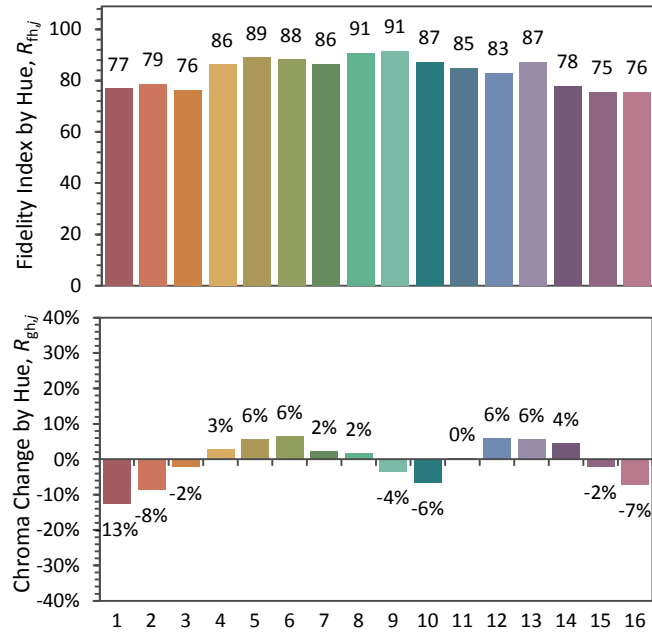
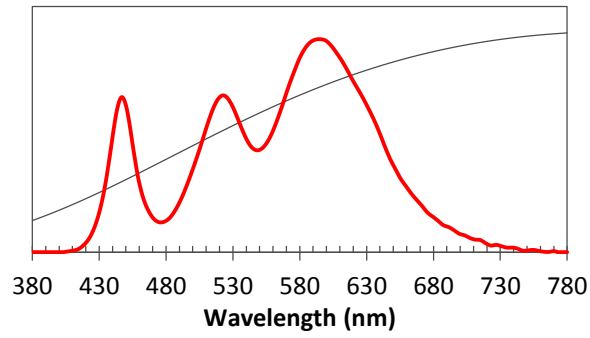
5,000 Real and Modelled* SPDs

*All modelled SPDs composed of combinations of Gaussian primaries; chromaticity on Planckian locus between 2700 K and 7000 K

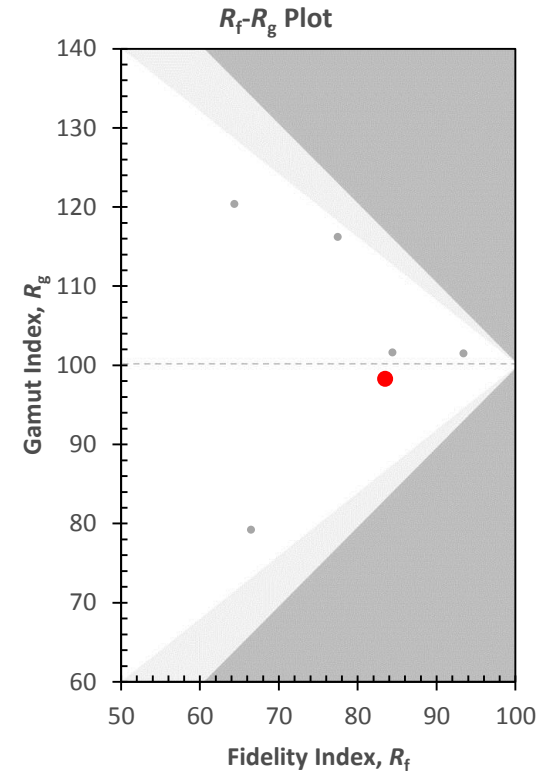
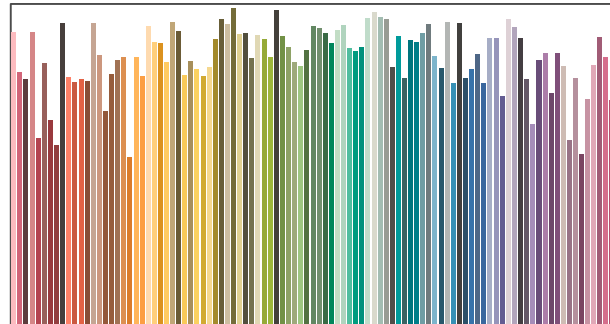


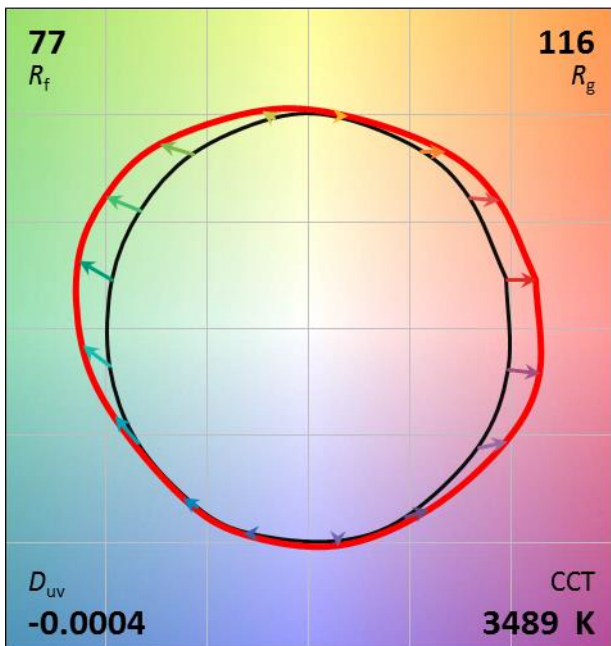
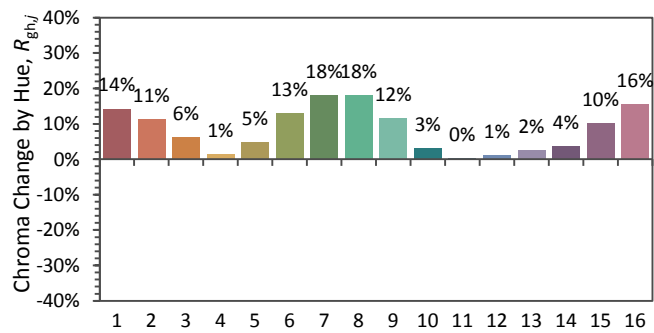
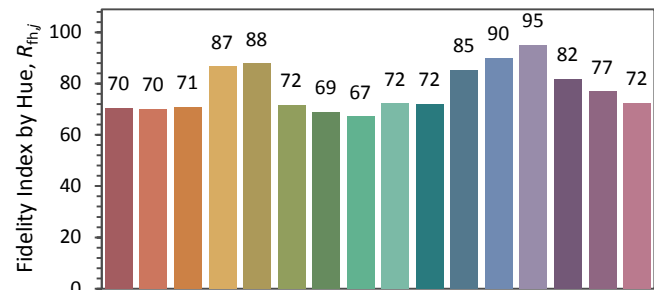
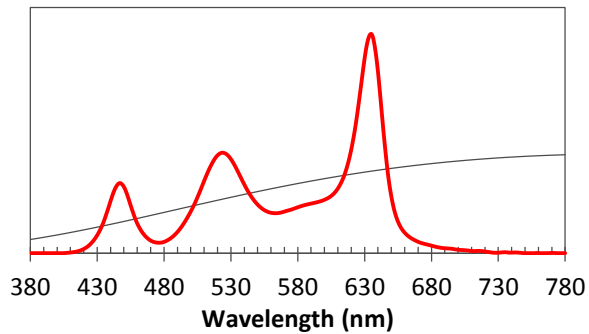
CRI R_a : 83, R_g : 21 LER: 311



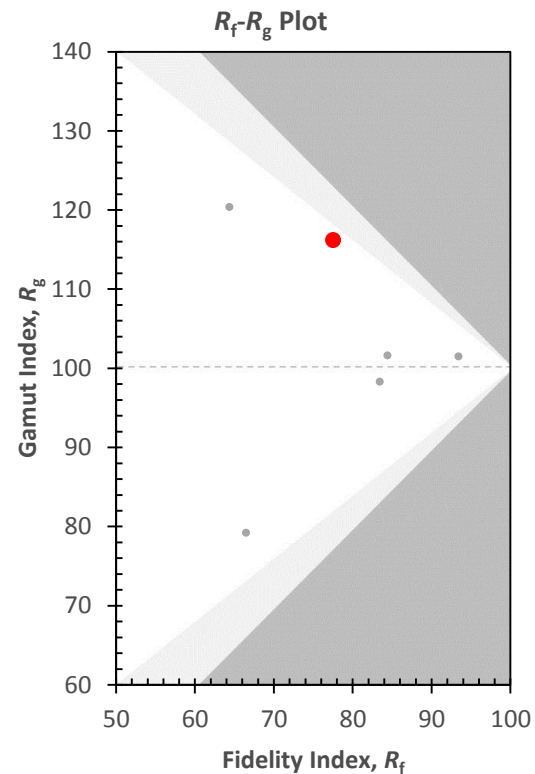
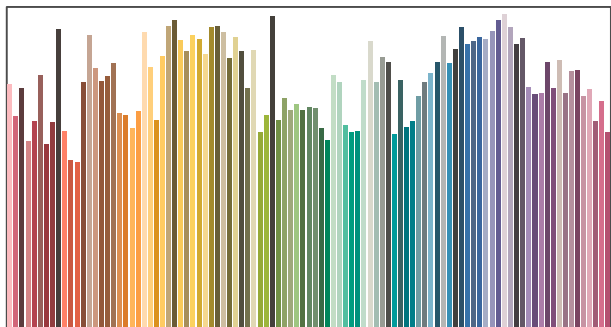


CRI R_a : 84, R_g : -7 LER: 343





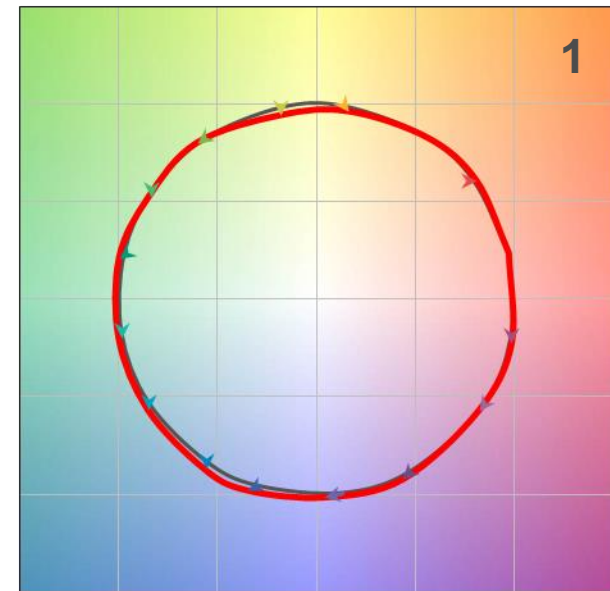
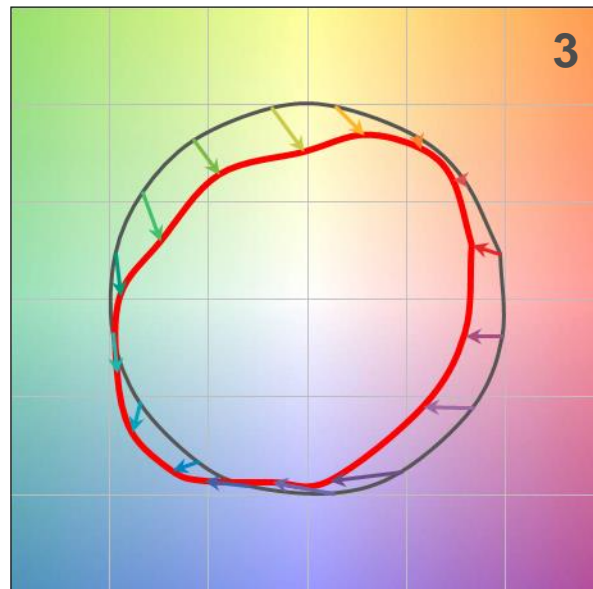
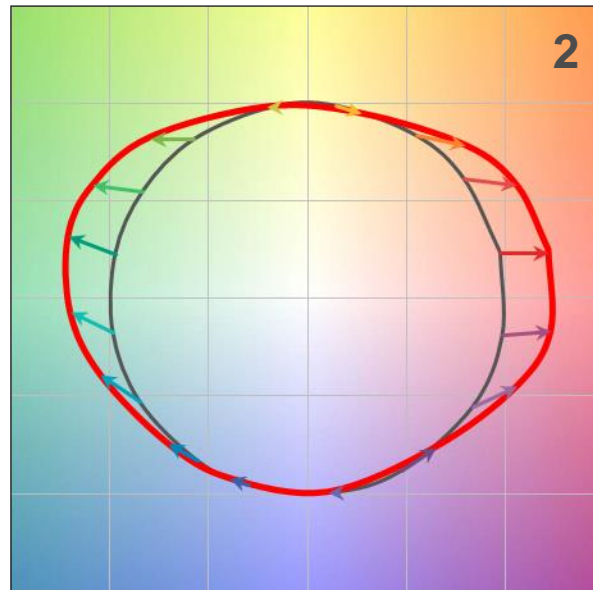
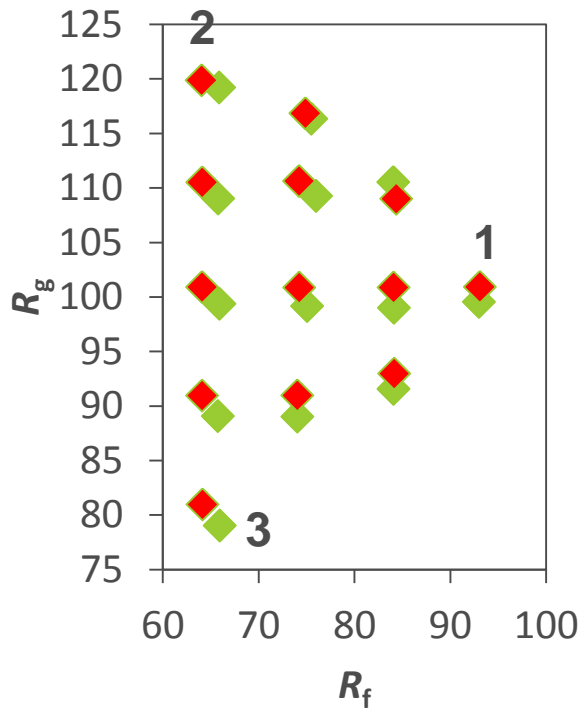
CRI R_a : 68, R_g : -12 LER: 305



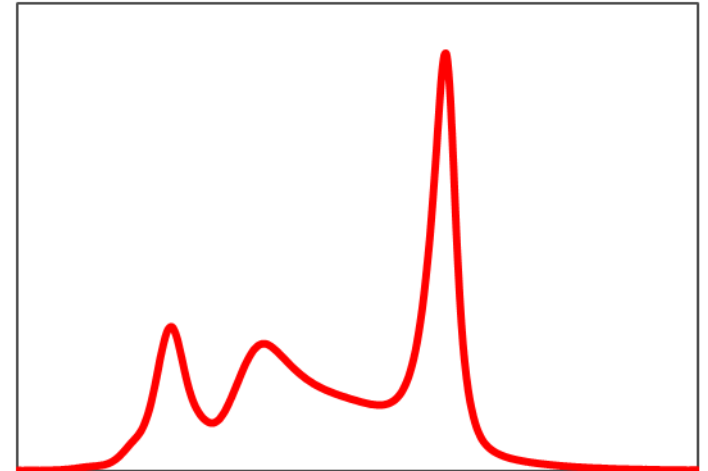
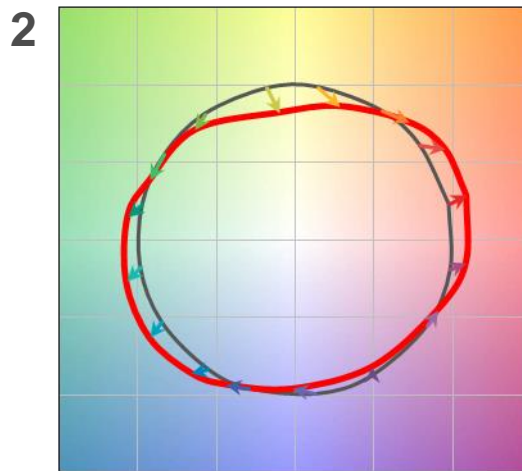
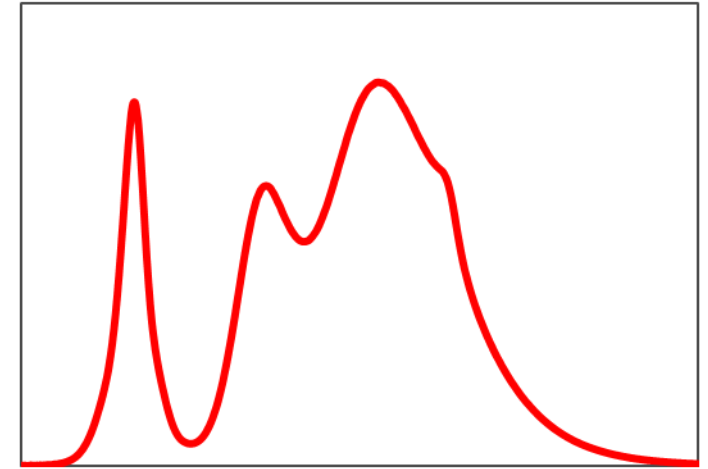
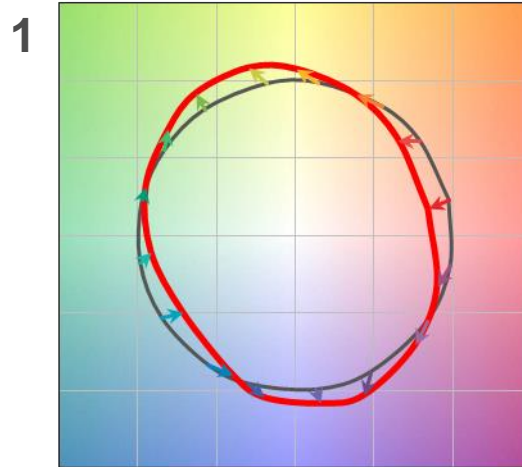
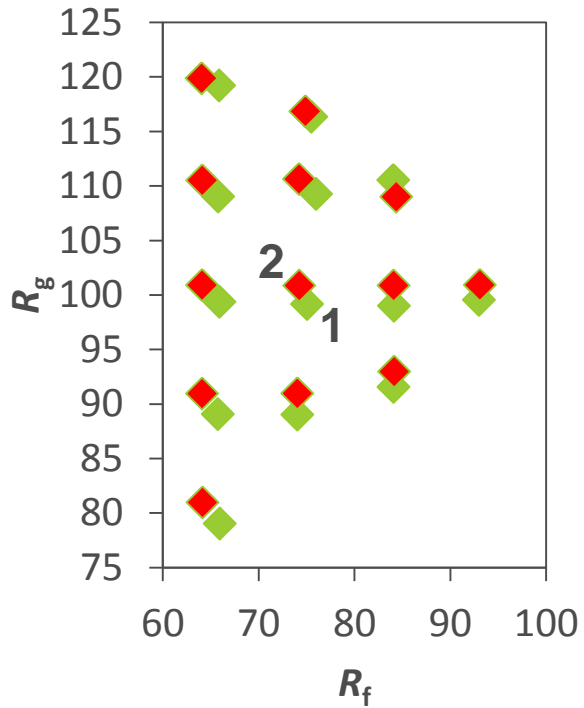
PNNL Research



Some Preliminary Data (in one space)

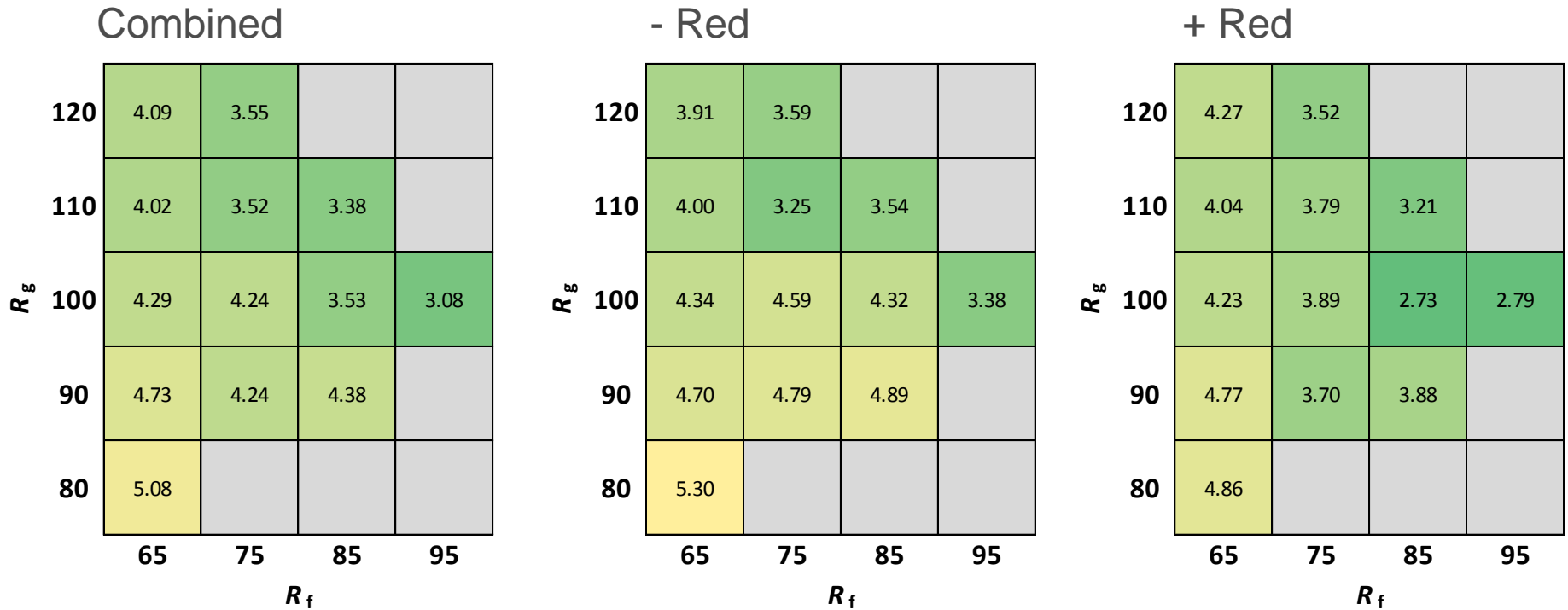


Some Preliminary Data (in one space)



Preliminary Experimental Data (in one space)

“Normalness”



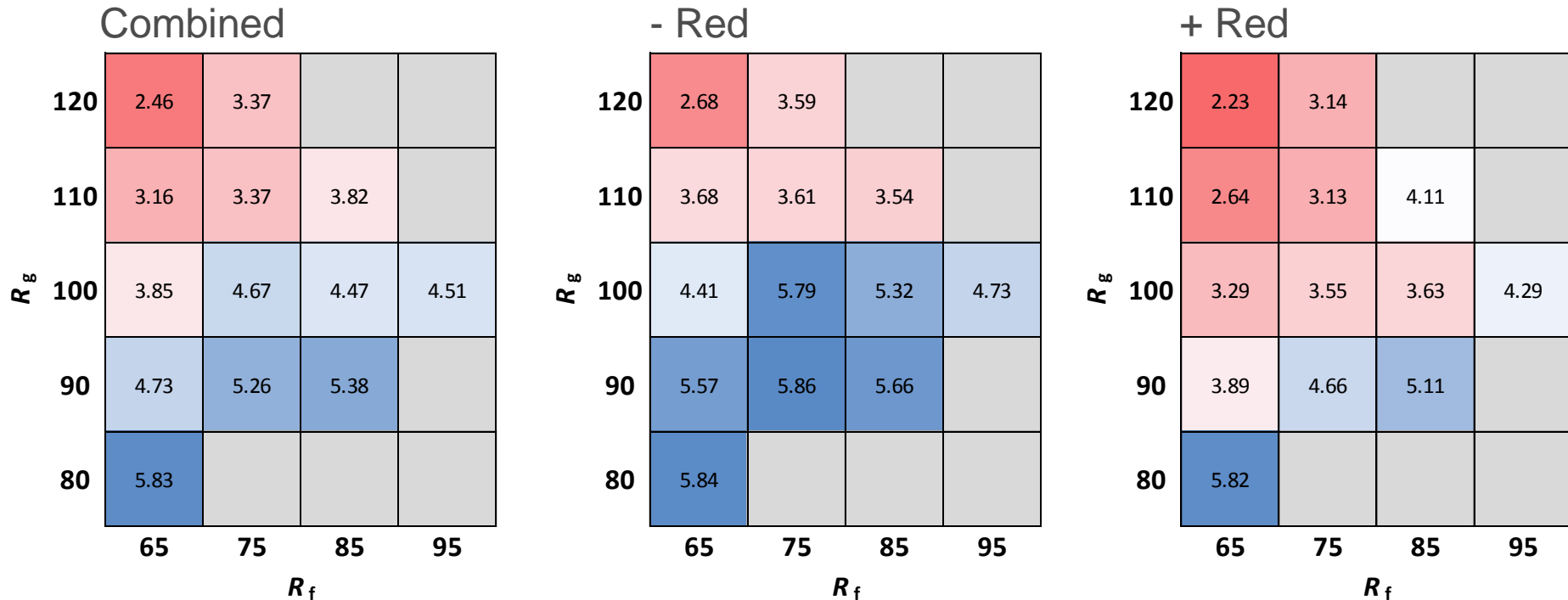
Normal



Shifted

Preliminary Experimental Data (in one space)

Saturation



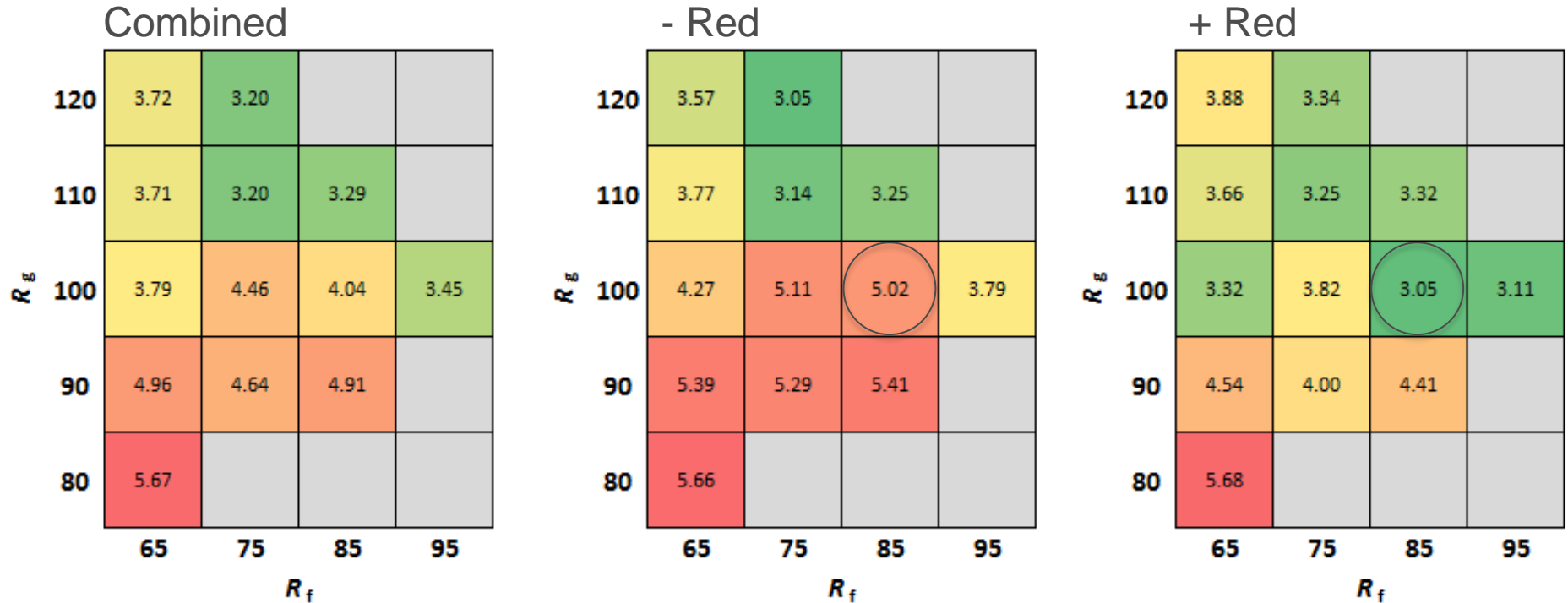
Saturated



Dull

Preliminary Experimental Data (in one space)

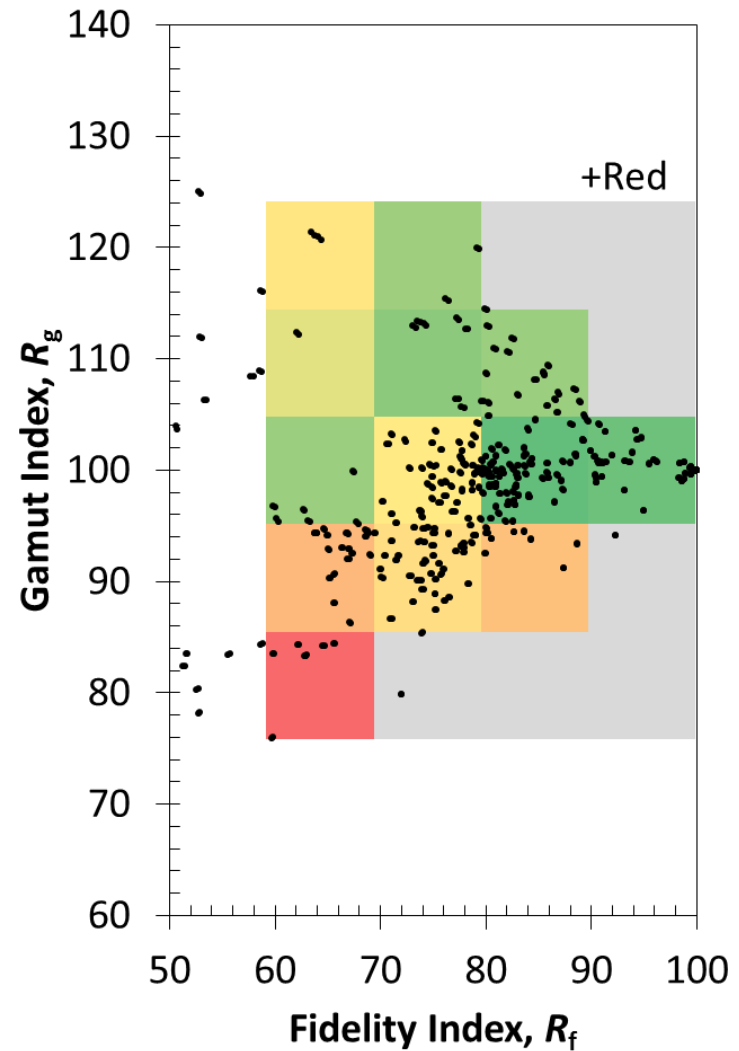
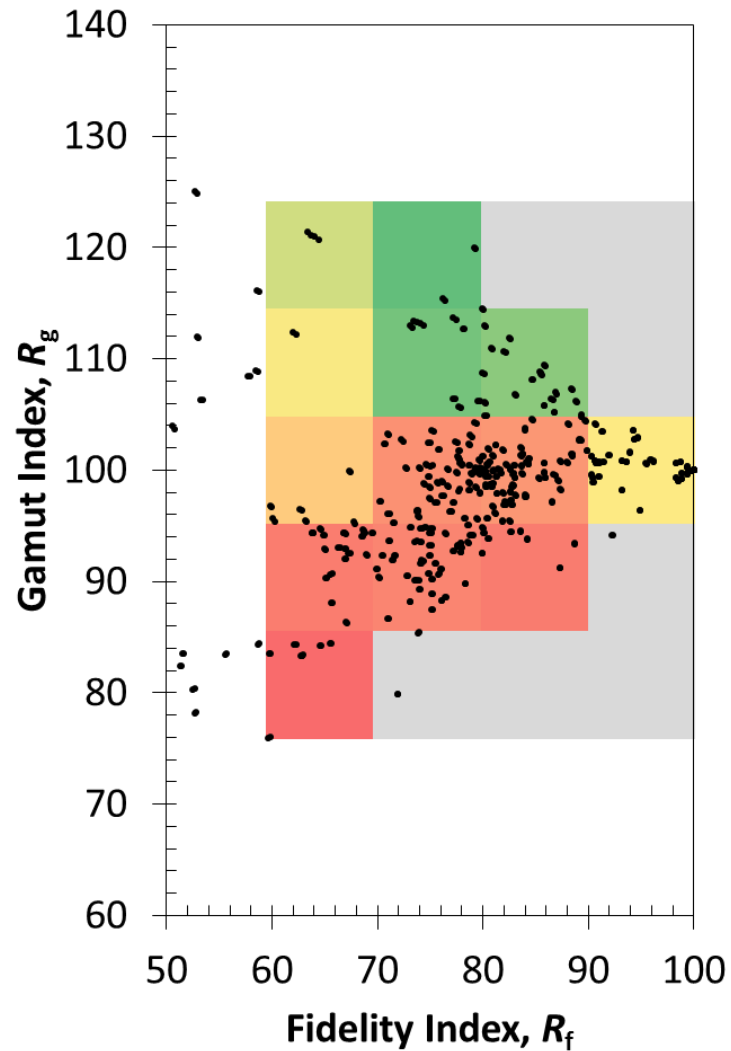
Preference



More Liked  Less Liked

Notes: CCT = 3500 K, Illuminance approximately 20 fc

Preliminary Experimental Data (in one space)



Future Activity

- Specifier's can use TM-30 immediately.
- Manufacturers are beginning to publish data; availability expected to increase.
 - Cycle to develop novel sources may take some time.
- Measurement equipment beginning to see software upgrades.
- Research into preference in various applications.
 - Short-term vs. long-term
- Need to determine application-specific design criteria.
 - Adoption by EE programs, etc.
- Different metric/system for consumers?
- Remember: Perception of sources doesn't change, even if ratings do.

TM-30 Resources

IES Technical Memorandum (TM) 30-15 (Includes Excel Calculators):

IES Method for Evaluating Light Source Color Rendition

<http://bit.ly/1IWZxVu>

Optics Express journal article that provides overview of the IES method:

Development of the IES method for evaluating the color rendition of light sources

<http://bit.ly/1J32ftZ>

Application webinar co-sponsored by US Department of Energy and Illuminating Engineering Society:

Understanding and Applying TM-30-15: IES Method for Evaluating Light Source Color Rendition

<http://1.usa.gov/1YEkbBZ>

Technical webinar co-sponsored by US Department of Energy and Illuminating Engineering Society:

A Technical Discussion of TM-30-15: Why and How it Advances Color Rendition Metrics

<http://1.usa.gov/1Mn15LG>

LEUKOS journal article supporting TM-30's technical foundations:

Smet KAG, David A, Whitehead L. 2015. **Why Color Space and Spectral Uniformity Are Essential for Color Rendering Measures.** *LEUKOS*. 12(1,2):39-50.

<http://dx.doi.org/10.1080/15502724.2015.1091356>

LEUKOS editorial discussing next steps:

Royer MP. 2015. **IES TM-30-15 Is Approved—Now What? Moving Forward with New Color Rendition Measures.** *LEUKOS*. 12(1,2):3-5.

<http://dx.doi.org/10.1080/15502724.2015.1092752>

Coming soon to Lighting Research and Technology:

Correspondence: In support of the IES method of evaluating light source colour rendition (More than 30 authors)