Technical Report

Evaluating Solid State and Tungsten-Halogen Lighting for Imaging Artwork via Computer Simulation

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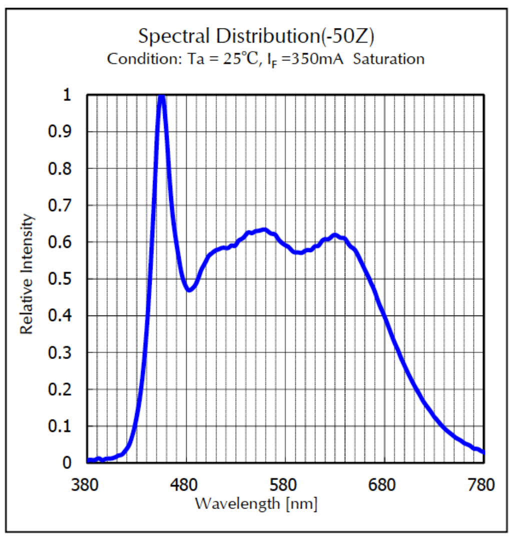

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Executive Summary

Solid-state lighting was evaluated for use as a taking illuminant in the imaging of artwork. Based on computer simulation of camera signals, a high color-rendering solid state light achieved the same accuracy as a Xenon strobe.

Report

A question was recently posed about the use of solid-state and tungsten-halogen lighting for high-accuracy museum imaging. In order to answer this question, a computational camera model was created using a calibration target's measured spectral reflectance factor for each patch, sensor spectral sensitivities, and the camera-taking illuminant spectral power distribution. The taking illuminant was either CIE D50 representing a Xenon strobe, a solid-state light, or 3200K Planckian representing tungsten-halogen lights. The model did not include any noise.

The solid-state lighting was Stanley GTDW1656JTE-50Z LED,* selected as an example of a high-color rendering source with a 5000K CCT. It has a CRI (Ra) of 95, an extremely high value for a solid-state lamp. Its spectrum is plotted in Fig. 1.

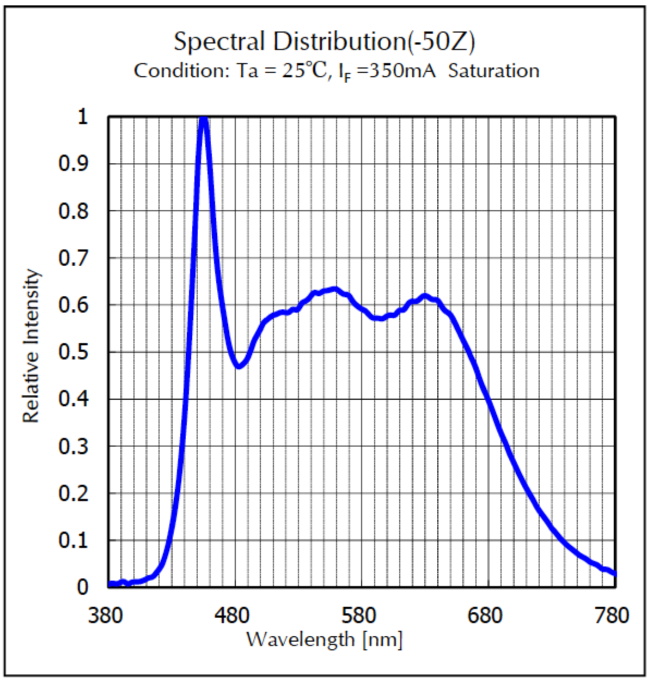

Fig. 1. Relative intensity of Stanley GTDW1656JTE-50Z LED (screen shot from their brochure).

The camera model consisted of a Dalsa FTF608C sensor and a Schott BG 39 with 3mm thickness as the IR cut-off filter, plotted in Fig. 2. Signals were calculated by integrating the product of the sensor, Schott filter, and the camera-taking illuminant,

* http://www.datasheets360.com/pdf/4111812215552935127?comp=6226&query=Stanley%2520GTDW1656JTE%252D50Z%2520

followed by normalization to equal area. In this manner, a perfect reflecting diffuser has an RGB signal of 1,1,1. A figure of merit, mu-factor, was calculated to determine how close the camera spectral sensitivities are to CIE color-matching functions.† A perfect camera has a mu-factor of 1.0. For the three taking illuminants of D50, solid state, and 3200K Planckian, all with viewing illuminant of D50, the values were 0.92, 0.90, and 0.91, respectively. Values above 0.9 indicate the camera system should have reasonable performance.

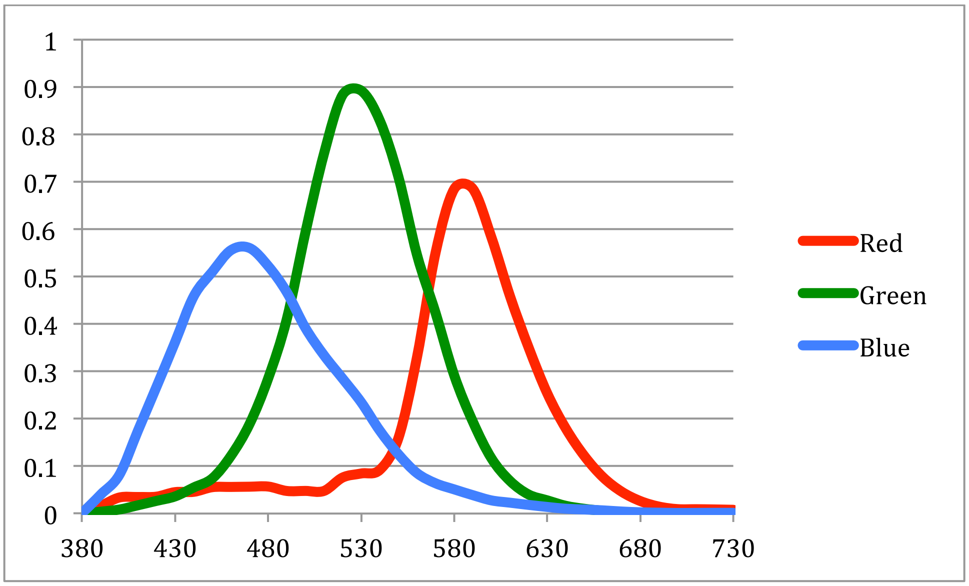

Fig. 2. Spectral sensitivities of a Dalsa FTF608C sensor and a 3mm Schott BG 39 absorption filter. Sensitivities are the product of the quantum efficiency multiplied by the filter transmittance.

The Xrite ColorChecker Classic was used to profile the imaging system using a (3x3) matrix transformation from RGB to XYZ for D50 and the 1931 standard observer. The matrix coefficients were determined by minimizing the average CIE94 color difference using nonlinear optimization. (CIE94 was used because the optimization was done using Excel and DE2000 is a pain to calculate.) Using a matrix for the profile produced reasonable results when evaluating the training data, shown in Figs. 3 – 5 including color difference data.

† Vora, P. L. and H. J. Trussell (1991). "Measure of goodness of a set of color scanning filters." Journal of the Optical Society of America A **10**: 8-23.

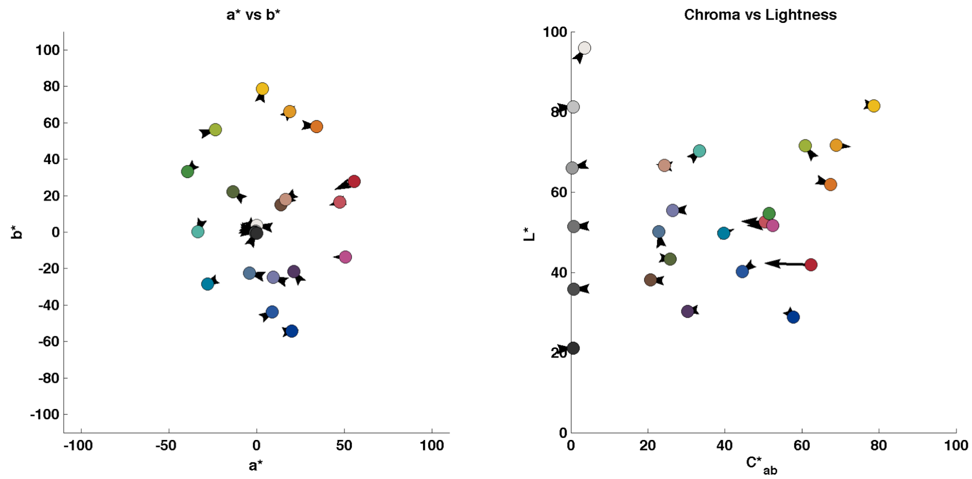

Fig. 3. ColorChecker calibration accuracy for Illuminant D50: 1.0 (3.5) Average (maximum) CIEDE2000

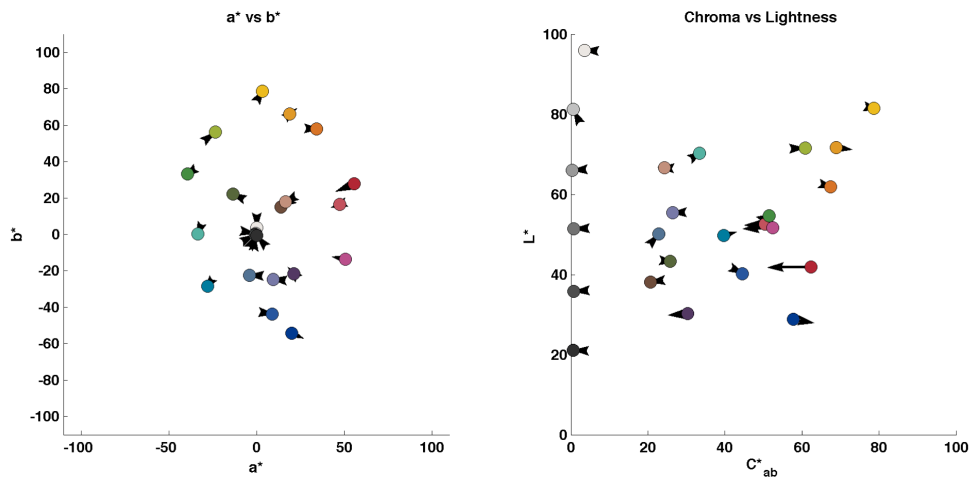

Fig. 4. ColorChecker calibration accuracy for Solid State: 1.2 (3.3) Average (maximum) CIEDE2000

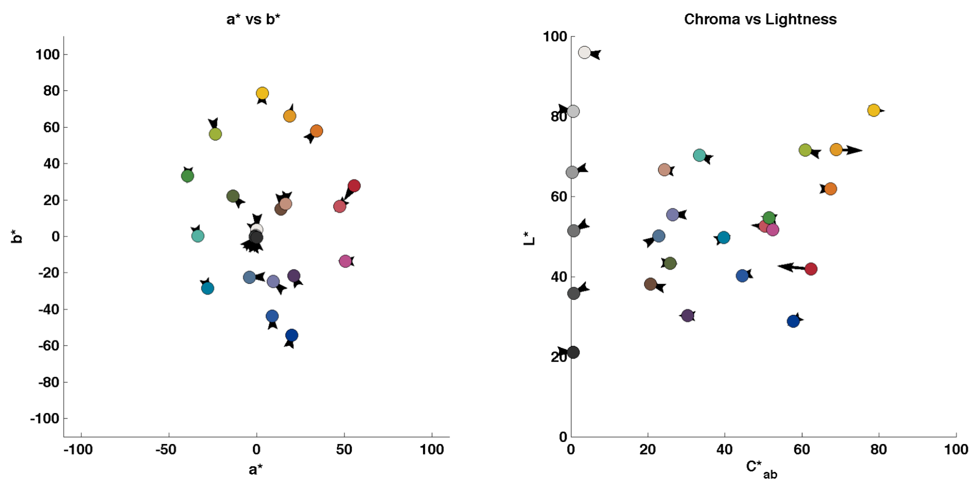

Fig. 5. ColorChecker calibration accuracy for 3200K: 0.9 (3.8) Average (maximum) CIEDE2000

The three profiles were used to evaluate the new Artist Paint Target,‡ shown in Fig. 6, (sold by Image Science Associates) as independent data. The specific pigments used to produce the target are listed in Table I. The performance is shown in Figs. 8 – 10.

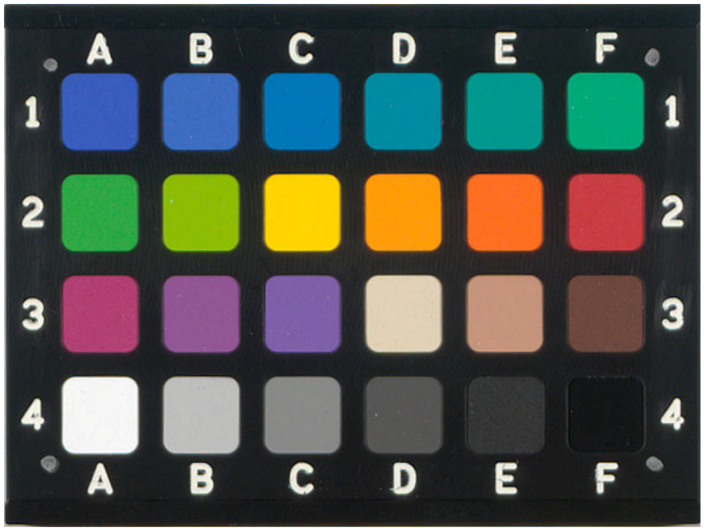

Fig. 6. sRGB image of the Artist Paint Target.

Table I. Paints used to produce the Artist Paint Target.

	A	B	C	D	E	F
1	Ultramarine Blue	Cobalt Blue	Phthalo Blue	Phthalo Blue Phthalo Green	Phthalo Green	Permanent Green Light
2	Permanent Green Light Hansa Yellow	Permanent Green Light Hansa Yellow	Hansa Yellow	Pyrrole Orange Hansa Yellow	Pyrrole Orange Hansa Yellow	Pyrrole Red
3	Quinacridone Magenta	Quinacridone Magenta Dioxazine Purple	Dioxazine Purple	Titan Bluff	Ultramarine Blue Yellow Ochre Quinacridone Crimson	Ultramarine Blue Yellow Ochre Quinacridone Crimson
4	Titanium White	Bone Black Raw Umber	Bone Black Raw Umber	Bone Black Raw Umber	Bone Black	Aktar Metal Velvet

‡ R. S. Berns, Artist Paint Target: A Tool for Verifying Camera Performance, Technical Report, June 2014. Download: http://www.rit.edu/cos/colorscience/mellon/pubs.php.

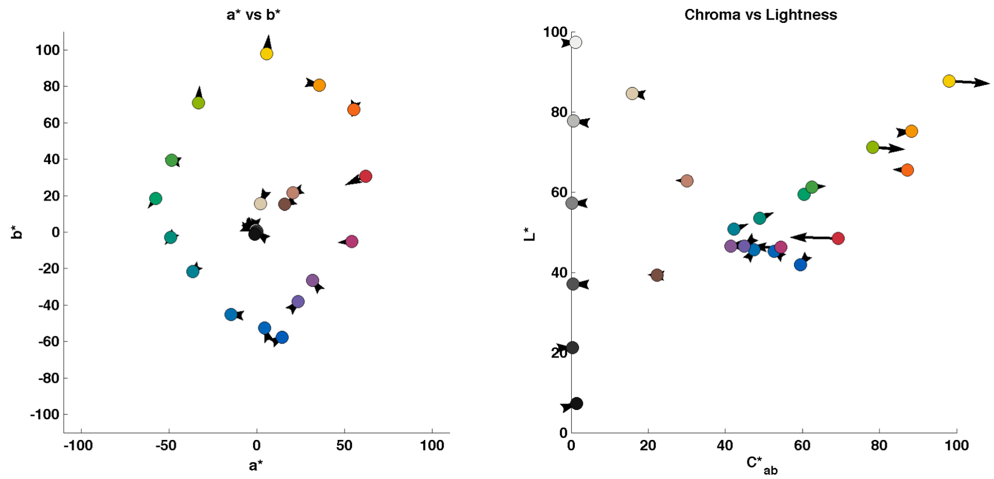

Fig. 8. Artist Paint Target evaluation accuracy for Illuminant D50: 1.4 (3.4) Average (maximum) CIEDE2000.

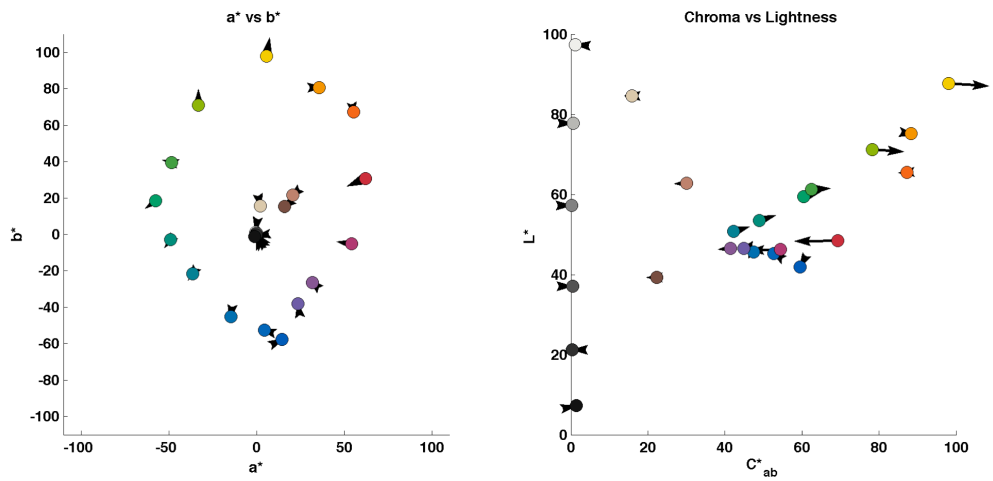

Fig. 9. Artist Paint Target evaluation accuracy for Solid State: 1.4 (3.2) Average (maximum) CIEDE2000.

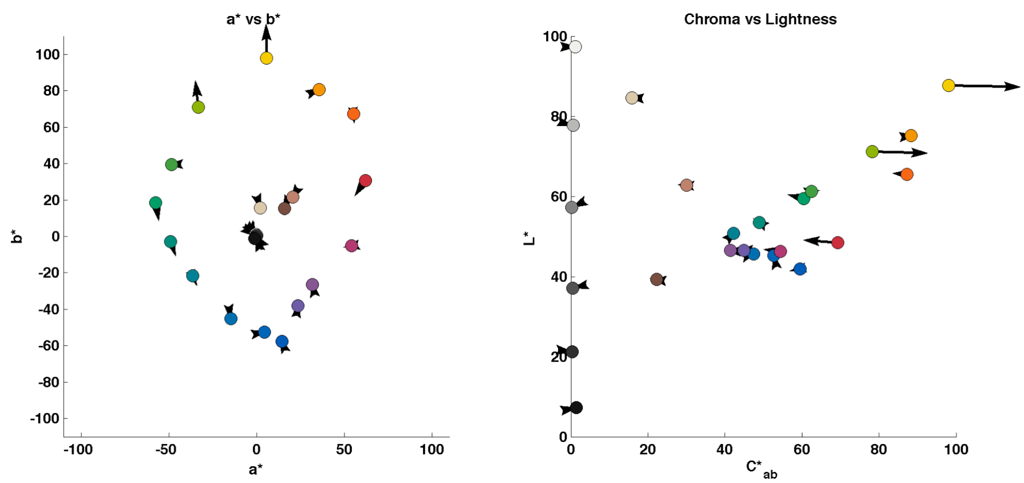

Fig. 10. Artist Paint Target evaluation accuracy for 3200K: 1.6 (4.9) Average (maximum) CIEDE2000.

The solid-state light was equivalent to D50 as a taking illuminant. The 3200K source was slightly worse than either light having a 5000K CCT. If the camera's spectral sensitivities were poorer approximations of color-matching functions, the errors would increase. This is shown in Fig. 11 for a tri-linear scanback using a 2700K incandescent taking illuminant.

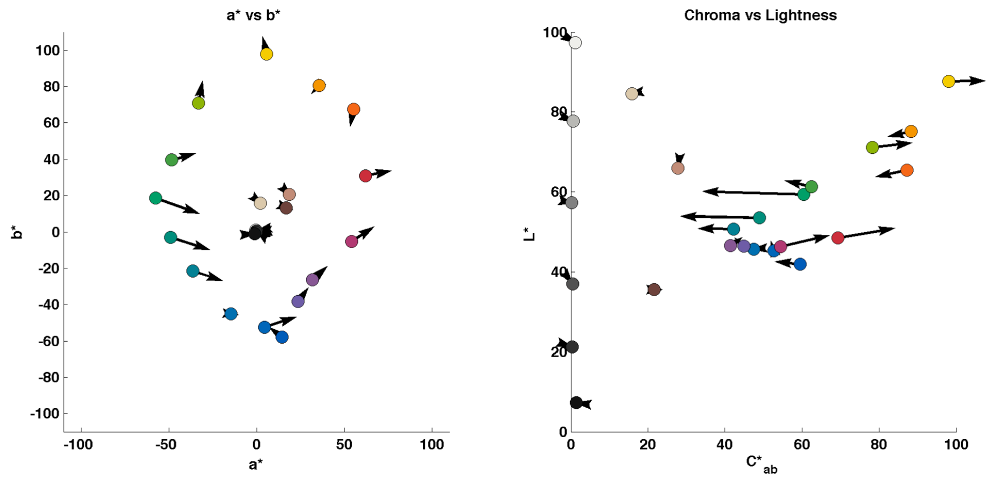

Fig. 11. Artist Paint Target evaluation accuracy for a tri-linear scanback with 2700K taking illuminant: 9.0 (26.1) Average (maximum) CIEDE2000.

In conclusion, a high color-rendering solid-state light appears to be a reasonable camera-taking illuminant. A tungsten-halogen lamp with a CCT near 3200K could also be effective. Solid-state lighting has the advantage of minimal heat and no UV emission. Based on this computational analysis, such lights should be tested in the studio, provided they can achieve sufficient luminance to minimize exposure times and produce uniform illumination.