Properties of LED – considering museum lighting

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Properties of LED
– considering museum lighting

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Contents

Solid State Lighting (SSL) i.e. LED based lighting is a “new” lighting technology that may offer many advantages for museum lighting.

- Light - Ultraviolet / Visible / Infrared
- Energy efficiency of LED packages and SSL products
- Light quality in color temperature and color rendering
- Maintenance of luminous flux and color
- Test and characterisation
Spectral properties of light

Light (visible light) is electromagnetic radiation in the visible range

In museum lighting we need to consider also UV and IR light

Photometry specifies the perceived brightness of light taking the human eye sensitivity into consideration (standard observer)

Radiometry specifies the radiant power in Watts (in a specific spectral range)

IR radiation

Infrared radiation, wavelengths > 780 nm will cause heat and related humidity variations
May cause surface hardening, discolouration and cracking

Rosenborg treasury, display case illumination

5 W bulbs
130-150 W
ΔT : 9-12 deg.

Custom LED
25-32 W
ΔT : < 1 deg.
UV radiation

useful to state the amount of UV per visible flux produced, in terms of microwatts per lumen (μW/lm)

<table>
<thead>
<tr>
<th>Light Source</th>
<th>UV Content (μW/lm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daylight</td>
<td>400 – 1500</td>
</tr>
<tr>
<td>Tungsten Incandescent</td>
<td>70 – 80</td>
</tr>
<tr>
<td>Tungsten halogen (incl. UV stop lamps)</td>
<td>40 – 170</td>
</tr>
<tr>
<td>Fluorescent</td>
<td>30 – 100</td>
</tr>
<tr>
<td>Metal halide</td>
<td>160 – 700</td>
</tr>
<tr>
<td>LEDs</td>
<td>&lt; 5</td>
</tr>
</tbody>
</table>

But UV LEDs and UV based white LEDs

LED packages, flux and efficiencies

LED packages

3 mm

(≈ 1-5 W, ~1000 lm)

Color temperature

2700 - 3500 K > 5000 K

(10-80 W, 1500-6000 lm)

Efficiency:

123 lm @ 350 mA ~ 117 lm/W

160 lm @ 350 mA ~ 152 lm/W (@ 25 °C)

139 lm @ 350 mA ~ 132 lm/W (@ 85 °C)

Lab results 2014: 303 lm/W
Status, SSL products

SSL products are based on LED packages including optics, heat sinks and driver electronics.

Retrofit products

- LED lamps (cap) - 50-100 lm/W
- LED modules (no cap)
- LED luminaires - ~ 90-110 lm/W

Colorimetry

Is used to describe the color of perceived light.

Color sensitivity of the standard observer
Color temperature

Different light sources

CCT is not enough
Duv is needed

Color rendering

Different spectral power distributions has the same CCT~3000K,
but very different color rendering:

<table>
<thead>
<tr>
<th>i</th>
<th>Appearance under daylight</th>
<th>Swatch</th>
<th>CRI</th>
<th>CRI</th>
<th>CRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Light greyish red</td>
<td>63.2</td>
<td>84.8</td>
<td>98.4</td>
<td>97.3</td>
</tr>
<tr>
<td>2</td>
<td>Dark greyish yellow</td>
<td>60.3</td>
<td>88.3</td>
<td>97.0</td>
<td>94.6</td>
</tr>
<tr>
<td>3</td>
<td>Strong yellow green</td>
<td>63.2</td>
<td>89.9</td>
<td>94.6</td>
<td>96.0</td>
</tr>
<tr>
<td>4</td>
<td>Moderate yellowish green</td>
<td>60.1</td>
<td>84.1</td>
<td>94.2</td>
<td>92.5</td>
</tr>
<tr>
<td>5</td>
<td>Light blush green</td>
<td>61.7</td>
<td>82.2</td>
<td>91.9</td>
<td>91.3</td>
</tr>
<tr>
<td>6</td>
<td>Light blue</td>
<td>70.4</td>
<td>81.9</td>
<td>89.4</td>
<td>86.8</td>
</tr>
<tr>
<td>7</td>
<td>Light violet</td>
<td>77.3</td>
<td>83.5</td>
<td>89.3</td>
<td>89.0</td>
</tr>
<tr>
<td>8</td>
<td>Light reddish purple</td>
<td>81.3</td>
<td>86.0</td>
<td>89.3</td>
<td>89.3</td>
</tr>
<tr>
<td>9</td>
<td>Strong red</td>
<td>35.5</td>
<td>35.5</td>
<td>35.5</td>
<td>35.5</td>
</tr>
<tr>
<td>10</td>
<td>Strong yellow</td>
<td>34.4</td>
<td>34.4</td>
<td>34.4</td>
<td>34.4</td>
</tr>
<tr>
<td>11</td>
<td>Strong green</td>
<td>50.1</td>
<td>83.6</td>
<td>93.8</td>
<td>93.8</td>
</tr>
<tr>
<td>12</td>
<td>Strong blue</td>
<td>41.6</td>
<td>82.4</td>
<td>92.5</td>
<td>92.5</td>
</tr>
<tr>
<td>13</td>
<td>Light yellowish pink (skin)</td>
<td>56.3</td>
<td>85.0</td>
<td>92.8</td>
<td>92.8</td>
</tr>
<tr>
<td>14</td>
<td>Moderate olive green (leaf)</td>
<td>96.2</td>
<td>95.4</td>
<td>95.4</td>
<td>95.4</td>
</tr>
</tbody>
</table>
Luminous flux maintenance

LEDs doesn’t fail suddenly, but degrades slowly –
Long term measurements of lumen maintenance of 48 retrofit LED lamps over 20,000 h

Established IES standard for LED packages: LM-80 and TM-21
New IES standards for LED lamps: LM-84-14 and TM-28-14
Need for accelerated test methods, with on/off cycling

Color maintenance

Correlated color temperature as a function of time:
Color maintenance

Color change even if CCT is constant, chromaticity coordinates as a function of time:

Test and characterisation

There is a need for characterisation of SSL products

- Spectral power distribution, UV, Vis (and IR)
- Luminous flux
- Efficiency
- Correlated Color temperature, Duv
- Color rendering index
- Luminous flux and color maintenance
- Relative damage factor
- Intensity distribution and color

- Illuminance, irradiance
- Double monochromator
- Handheld spectrometer
Test and characterisation

Draft international test standard has been published:

- EN 13032 Lighting Applications - Measurement and presentation of photometric data of lamps and luminaires - Part 4: LED lamps, modules and luminaires

tested through an interlaboratory comparison IC2013 by the IEA SSL Annex 2010-2014 + 2014-2019

110 laboratories

Conclusion

Solid State Lighting (SSL) i.e. LED based lighting is a “new” lighting technology that offers

- Limited UV and IR radiation
- High energy efficiency
- High light quality in color temperature and color rendering
- Long life time
- Color tunability
- Dimming, sensor based system to reduce exposure
- Need to test and characterise

Thank you to all my coworkers at the LED team at DTU Fotonik, and for your kind attention