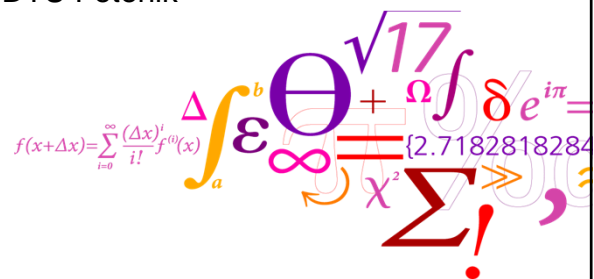




# Properties of LED

## – considering museum lighting

Carsten Dam-Hansen, DTU Fotonik



DTU Fotonik  
Department of Photonics Engineering

DTU Fotonik  
Department of Photonics Engineering




### 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

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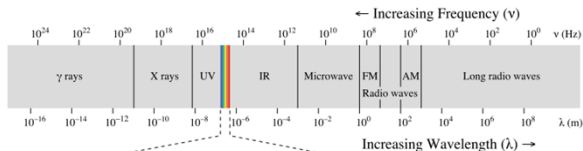
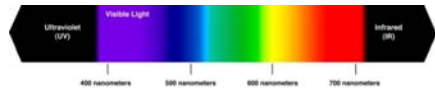
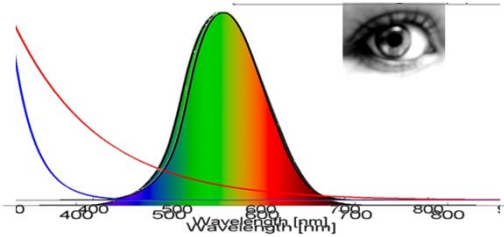
## Spectral properties of light

**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)**

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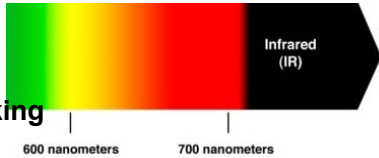



## IR radiation

**Infrared radiation, wavelengths > 780 nm will cause heat and related humidity variations**

**May cause surface hardening, discolouration and cracking**

**Rosenborg treasury, display case illumination**

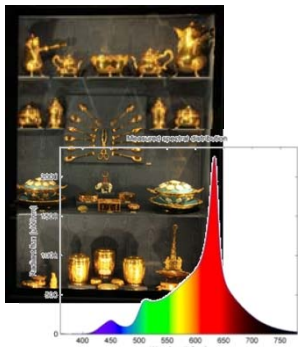




**5 W bulbs**

**130-150 W**

**ΔT : 9-12 deg.**



**Custom LED**


**25-32 W**

**ΔT : < 1 deg.**

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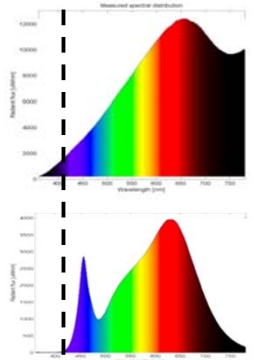
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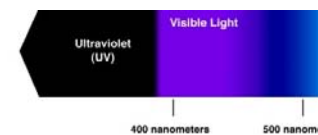


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## UV radiation

useful to state the amount of UV per visible flux produced, in terms of microwatts per lumen ( $\mu\text{W}/\text{lm}$ )






Light Source	UV Content ( $\mu\text{W}/\text{lm}$ )
Daylight	400 – 1500
Tungsten Incandescent	70 – 80
Tungsten halogen (incl. UV stop lamps)	40 – 170
Fluorescent	30 – 100
Metal halide	160 – 700
LEDs	< 5

CIE 157:2004

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## LED packages, flux and efficiencies

LED packages

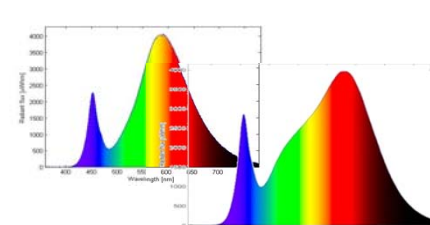


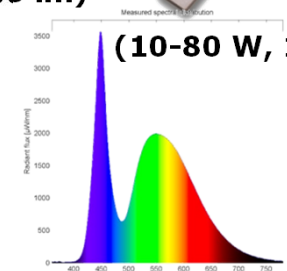
3 mm  
(~ 1-5 W, ~1000 lm)

Color temperature

2700 - 3500 K      > 5000 K

Efficiency:  
123 lm @ 350 mA ~ 117 lm/W





(10-80 W, 1500-6000 lm)

160 lm @ 350 mA ~ 152 lm/W (@ 25 °C)  
139 lm @ 350 mA ~ 132 lm/W (@ 85 °C)

Lab results 2014: 303 lm/W

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**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 luminaires**



~ 90-110 lm/W

**LED modules (no cap)**

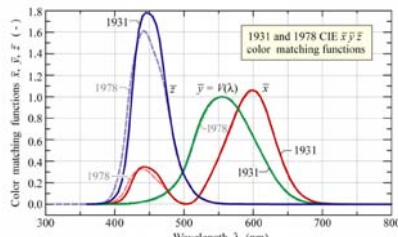


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**Colorimetry**

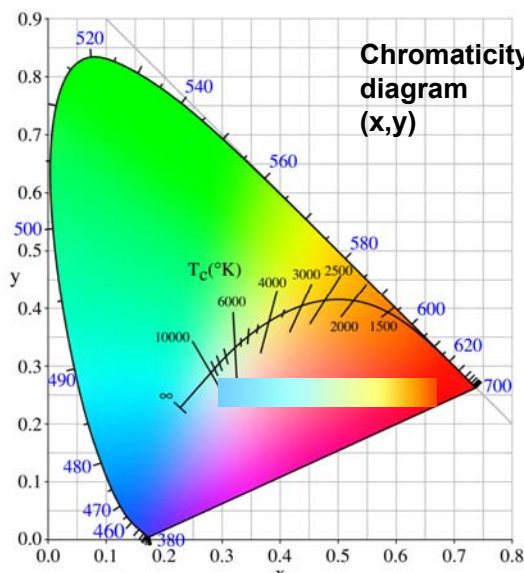
Is used to describe the color of perceived light



Color matching functions  $\bar{x}$ ,  $\bar{y}$ ,  $\bar{z}$  (-)

Wavelength  $\lambda$  (nm)

1931 and 1978 CIE  $\bar{x}$ ,  $\bar{y}$ ,  $\bar{z}$  color matching functions

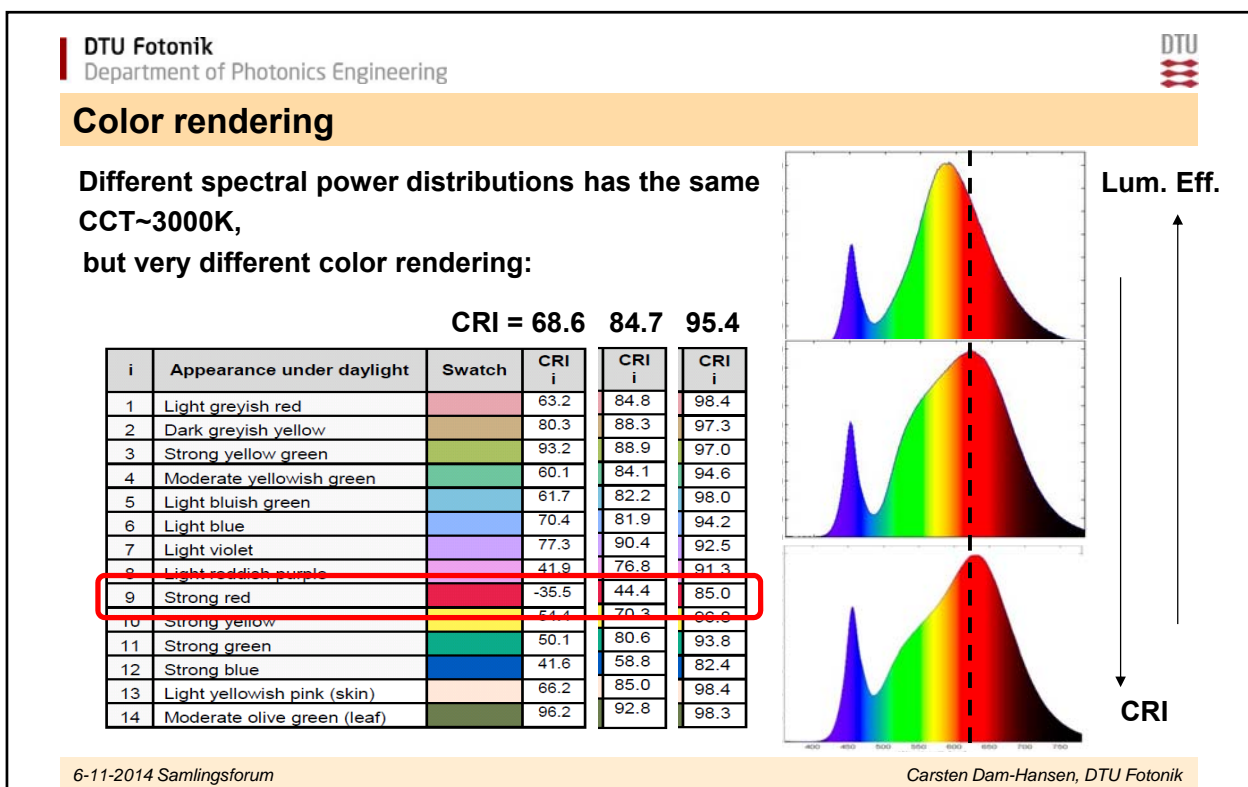
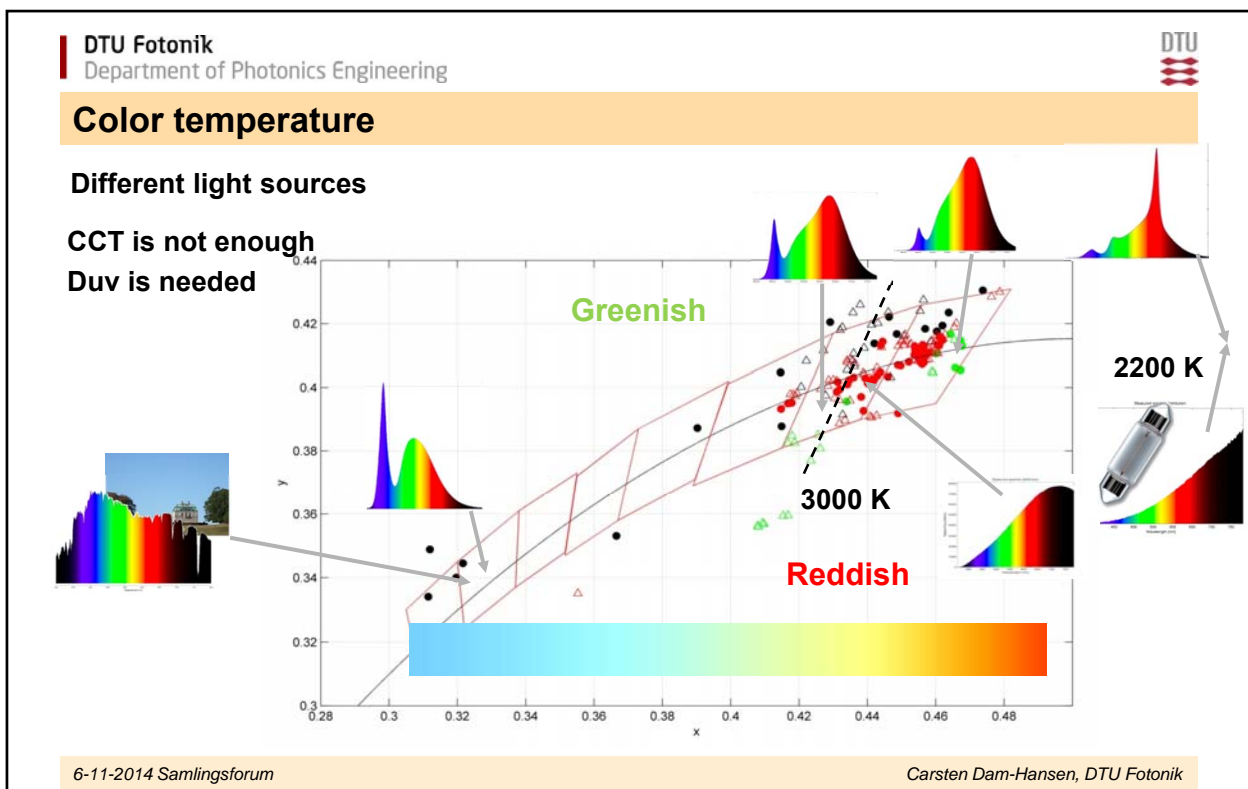


Chromaticity diagram (x,y)


$T_c(^{\circ}K)$

**Color sensitivity of the standard observer**

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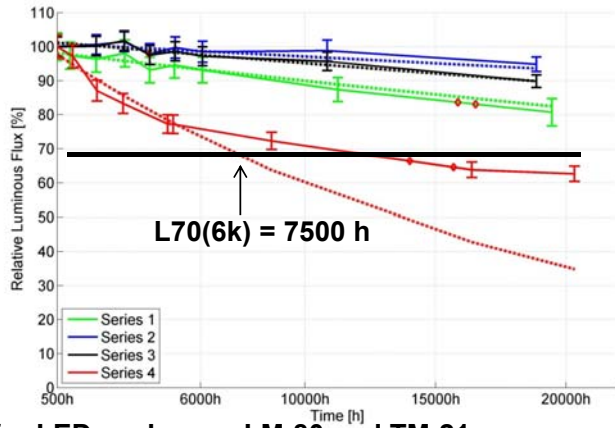
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## Luminous flux maintenance

**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**

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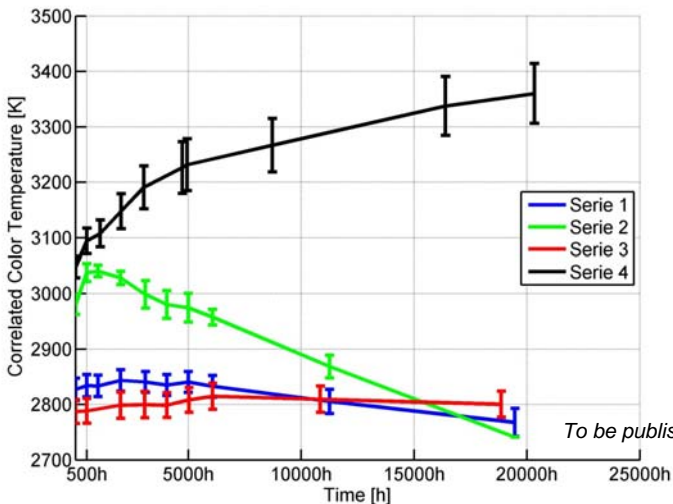
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## Color maintenance

**Correlated color temperature as a function of time:**





*To be published*

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## Color maintenance

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

*To be published*

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## 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

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## Test and characterisation

**Draft international test standard has been published:**

**CIE DIS 025/E:2014 Test Method for LED Lamps, LED Luminaires and LED Modules**

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

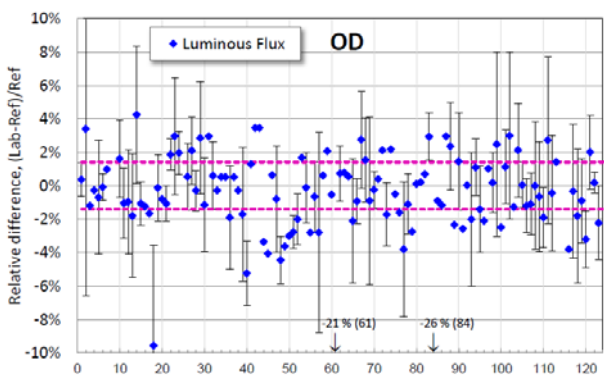
**tested through an interlaboratory comparison IC2013 by the**

4

**IEA SSL Annex**  
2010-2014 + 2014-2019


Efficient Electrical End-Use Equipment  
International Energy Agency

**110 laboratories**



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## 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**

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