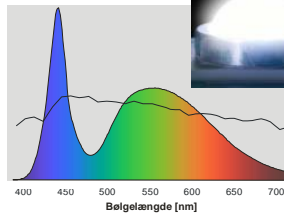
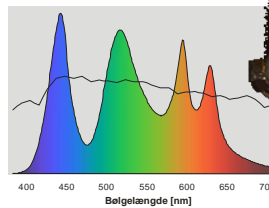


Farveegenskaber

og forskning i lysdioder



Carsten Dam-Hansen



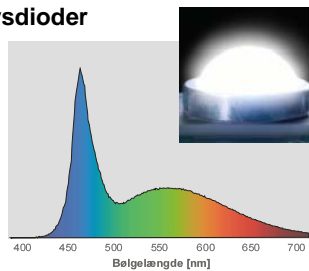
*Birgitte Thestrup, Anders Thorseth, Peter Jensen og Paul Michael Petersen
LaserSystemer og Optiske materialer, Risø – DTU*

Hvidt lys med LED, farveegenskaber

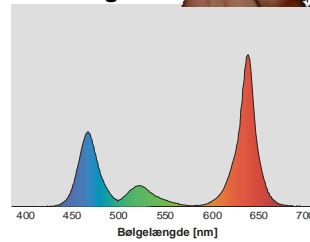
Fordele: kompakte, robuste enheder med høj lysstrøm
høj energieffektivitet, lang levetid, dæmpning
ingen IR-stråling og UV-stråling
smalbandede farvede lyskilder
farveegenskaber?

Hvidt lys med LEDs kan opnås på to måder:

Hvide lysdioder

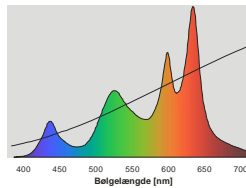




RGB-teknologi



Farvegengivelse, Ra-indeks

- Farvegengivelsen af en hvid lyskilde er den effekt lyskilden har på farvefremtoningen af objekter sammenlignet med farvefremtoningen under en reference lyskilde
- CIE 13.3-1995 angiver metode til måling og specificering af Ra-indeks (eng. Color rendering index CRI)



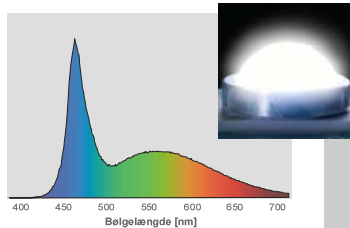
Test 
Reference
(samme CCT) 

| i | Test object color | CRI |
|----|--------------------------|------|
| 1 | Light greyish red | 92,4 |
| 2 | Dark greyish yellow | 99,1 |
| 3 | Strong yellow green | 89,5 |
| 4 | Moderate yellowish green | 82,3 |
| 5 | Light bluish green | 92,3 |
| 6 | Light blue | 92,8 |
| 7 | Light violet | 94,4 |
| 8 | Light reddish purple | 90,9 |
| 9 | Strong red | 71,8 |
| 10 | Strong yellow | 95,7 |
| 11 | Strong green | 71,0 |
| 12 | Strong blue | 93,6 |
| 13 | Light yellowish pink | 92,4 |
| 14 | Moderate olive green | 91,5 |

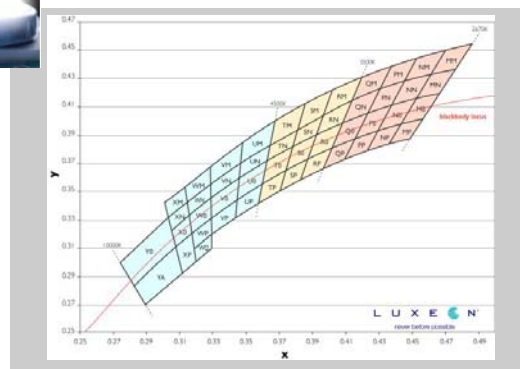
- Hvis spektralfordelingen af test og reference lyskilde er identiske haves at $R_a = 100$
- Man kan ikke sammenligne lyskilders farvegengivelse hvis de ikke har samme farvetemperatur

Hvide LEDs

Blå LED coated med fosforescerende materiale, som absorberer blå lys og udsender lys med længere bølgelængder

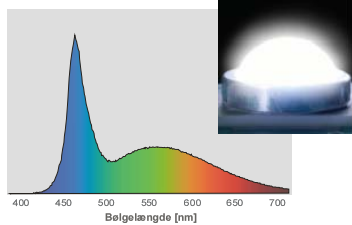


CCT i området :
2600 - 3500 K (varm)
3500 - 5000 K (neutral)
5000 - 10.000 K (kold)



Hvide LEDs

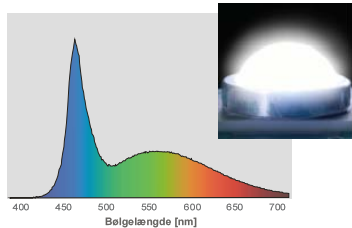
Blå LED coated med fosforescerende materiale, som absorberer blå lys og udsender lys med længere bølgelængder



| | | |
|--------------------------------|------------------|---------------------------|
| CCT i området : | Ra-indeks | Effektivitet |
| 2600 - 3500 K (varm) | ca. 80 | 59 lm/W (99 lm/W) |
| 3500 - 5000 K (neutral) | ca. 75 | |
| 5000 - 10.000 K (kold) | ca. 70 | 85 lm/W (129 lm/W) |
| | | @ 350 mA ca. 1.2 W |

Hvide LEDs

Blå LED coated med fosforescerende materiale, som absorberer blå lys og udsender lys med længere bølgelængder



| | | |
|--------------------------------|------------------|-------------------------------------|
| CCT i området : | Ra-indeks | Ra-indeks målinger |
| 2600 - 3500 K (varm) | ca. 80 | 81.5 @ 2858 K, 81.9 @ 3160 K |
| 3500 - 5000 K (neutral) | ca. 75 | |
| 5000 - 10.000 K (kold) | ca. 70 | 79.4 @ 7199 K |

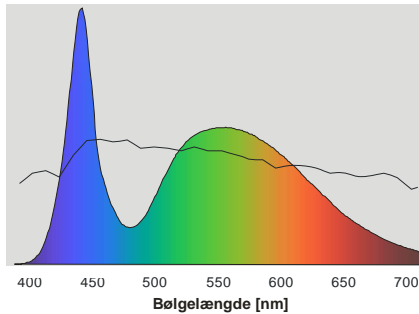
Hvide LEDs

Måling for kold hvid LED

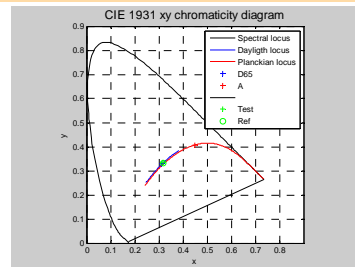
$I = 700 \text{ mA}$, $T = 25^\circ \text{ C}$

$\Phi = 101 \text{ lm}$

$\text{CCT} = 6207 \text{ K}$



$R_a = 74$ (Daylight 6207 K)



R_a -indeks

| i | Test object color | CRI |
|----|--------------------------|-------|
| 1 | Light greyish red | 71,7 |
| 2 | Dark greyish yellow | 78,3 |
| 3 | Strong yellow green | 81,0 |
| 4 | Moderate yellowish green | 74,6 |
| 5 | Light bluish green | 72,6 |
| 6 | Light blue | 69,5 |
| 7 | Light violet | 83,5 |
| 8 | Light reddish purple | 62,4 |
| 9 | Strong red | -21,1 |
| 10 | Strong yellow | 46,5 |
| 11 | Strong green | 70,9 |
| 12 | Strong blue | 43,5 |
| 13 | Light yellowish pink | 72,8 |
| 14 | Moderate olive green | 89,3 |

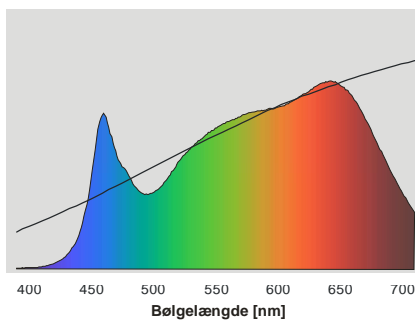
Hvide LEDs

Måling for varm hvid LED

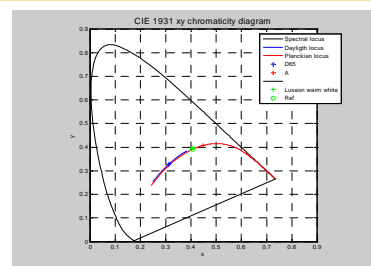
$I = 350 \text{ mA}$, $T_a = 25^\circ \text{ C}$

$\Phi = 23.8 \text{ lm}$,

$\text{CCT} = 3500 \text{ K}$



$R_a = 93$ (Planckian 3500 K)

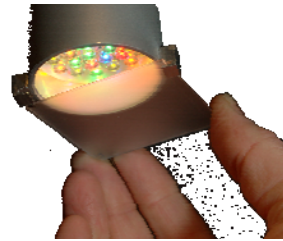


R_a -indeks

| i | Test object color | CRI |
|----|--------------------------|------|
| 1 | Light greyish red | 94,6 |
| 2 | Dark greyish yellow | 98,4 |
| 3 | Strong yellow green | 98,7 |
| 4 | Moderate yellowish green | 87,3 |
| 5 | Light bluish green | 91,0 |
| 6 | Light blue | 95,7 |
| 7 | Light violet | 92,0 |
| 8 | Light reddish purple | 89,6 |
| 9 | Strong red | 81,4 |
| 10 | Strong yellow | 92,9 |
| 11 | Strong green | 86,1 |
| 12 | Strong blue | 70,4 |
| 13 | Light yellowish pink | 95,8 |
| 14 | Moderate olive green | 98,4 |

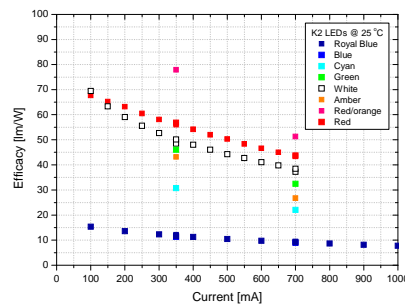
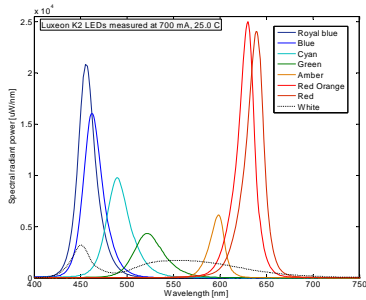
Spektralt design

Spektralt design ud fra flere farver i det synlige spektrum giver unik design frihed og mulighed for at optimere farvegengivelse

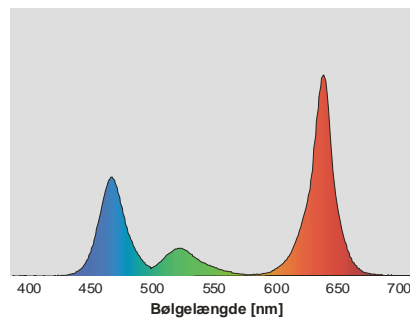
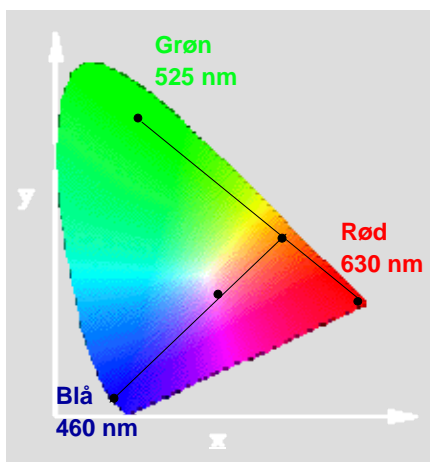


K2 LEDs fra LumiLeds (2006)

Målt spektral flux [$\mu\text{W}/\text{nm}$] og effektivitet [lm/W]:



Spektralt design med RGB teknologi



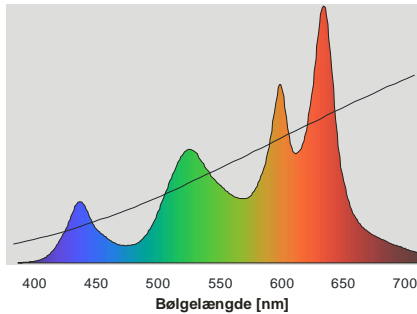
- numerisk optimering af farvetemperatur og Ra-indeks
- intelligent styring og regulering

Spektralt design

Måling for LED lyskilde "glødepære"

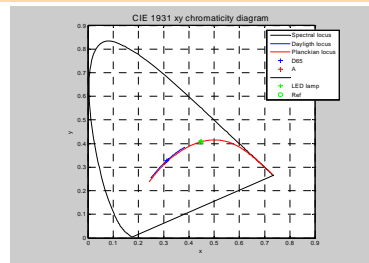
Farvetemperatur: 2872 K

Effektivitet: 27 lm/W



R_a -indeks

$R_a = 92$ (Planckian 2872 K)



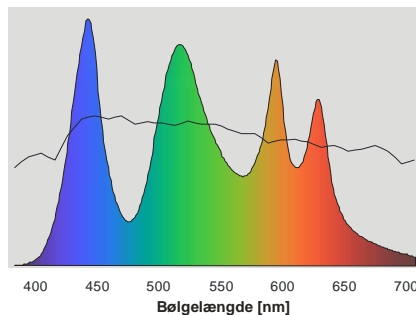
| i | Test object color | CRI |
|----|--------------------------|------|
| 1 | Light greyish red | 92,4 |
| 2 | Dark greyish yellow | 93,1 |
| 3 | Strong yellow green | 89,5 |
| 4 | Moderate yellowish green | 82,3 |
| 5 | Light bluish green | 92,3 |
| 6 | Light blue | 92,8 |
| 7 | Light violet | 94,4 |
| 8 | Light reddish purple | 90,9 |
| 9 | Strong red | 71,8 |
| 10 | Strong yellow | 95,7 |
| 11 | Strong green | 71,0 |
| 12 | Strong blue | 93,6 |
| 13 | Light yellowish pink | 92,4 |
| 14 | Moderate olive green | 91,5 |

Spektralt design

Måling for LED lyskilde "dagslys"

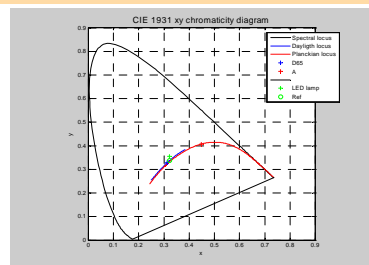
Farvetemperatur: 5981 K

Effektivitet: 24 lm/W



R_a -indeks

$R_a = 91$ (Daylight 5981 K)

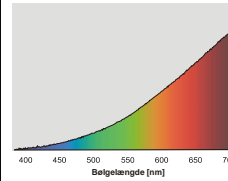


| i | Test object color | CRI |
|----|--------------------------|------|
| 1 | Light greyish red | 95,2 |
| 2 | Dark greyish yellow | 91,0 |
| 3 | Strong yellow green | 89,0 |
| 4 | Moderate yellowish green | 90,6 |
| 5 | Light bluish green | 92,7 |
| 6 | Light blue | 91,6 |
| 7 | Light violet | 94,0 |
| 8 | Light reddish purple | 81,2 |
| 9 | Strong red | 36,3 |
| 10 | Strong yellow | 78,7 |
| 11 | Strong green | 82,3 |
| 12 | Strong blue | 64,5 |
| 13 | Light yellowish pink | 94,7 |
| 14 | Moderate olive green | 93,4 |

LED belysning - Rosenborg

Varm "kold" belysning til skatkammer montre
 On-site spektraldesign med LED demolyskilde og reference lyskilde

Computerstyret LED lys



Reference:
 pinolpære ved 2200 K

LED belysning - Rosenborg

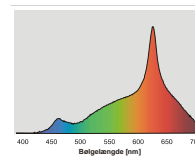
Varm "kold" belysning til skatkammer montre



Varm hvid LED
 CCT = 2960 K
 Ra = 90



CCT = 2200 K
 Ra = 95



Tak for opmærksomheden

Berøringsløs temperaturmonitorering

