New LED Lighting in Display Cases at Rosenborg Castle

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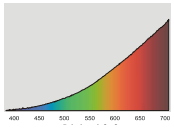
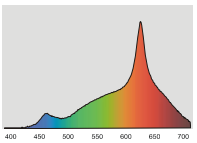
Department of Photonics Engineering

Technical University of Denmark

Energy efficient and high quality LED illumination system for display cases





Carsten Dam-Hansen, DTU Fotonik

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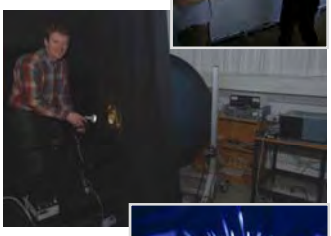
DTU Fotonik, Department of Photonics Engineering

Educational and research institute at the Technical University of Denmark
Telecommunication and optical technologies
190 employees incl. 60 Ph.D.-students
80 M.Sc. candidates and 15 Ph.D students per year

LED group:
Research projects on LEDs, materials and characterisation



Master course on LED and PV technology
Annual Industrial LED conference/workshop

Application specific R&D projects in collaboration with Danish industry and Danish Energy Association

Test & characterisation of LED systems/products

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R&D project

Research and development project on energy efficient and high quality lighting. Collaboration between:

The Royal Danish Collections, Hazze Nyström
Lumodan, Brian Markussen
DTU Fotonik, Department of Photonics Engineering

Financed by the Danish Energy Association under ELFORSK grant no. PSO 339-029

Kvorning Design & Kommunikation

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The exhibition display cases

Rosenborg Castle, Copenhagen

The Royal Danish Collections
Denmark's greatest cultural treasures

The Treasury in the Palace basement

Crown Jewels and the Danish Crown Regalia

High security display cases

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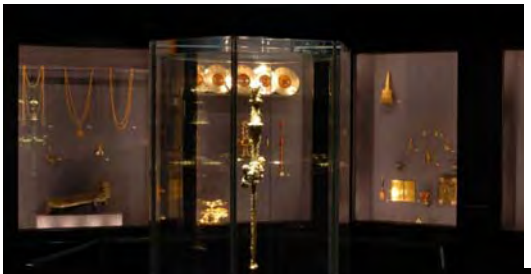
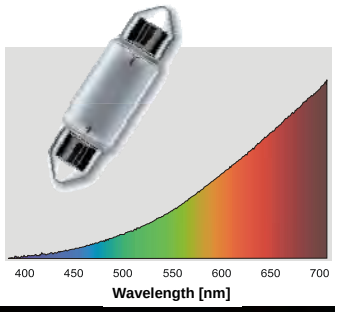
The present illumination

5 W pinol incandescent bulbs





Warm and reddish light, CCT = 2200 K
Color rendering, CRI ~ 99

Energy inefficient, < 3 % visible light ~ 5 lm/W
Dimming through number of bulbs
130 – 150 W pr. display case

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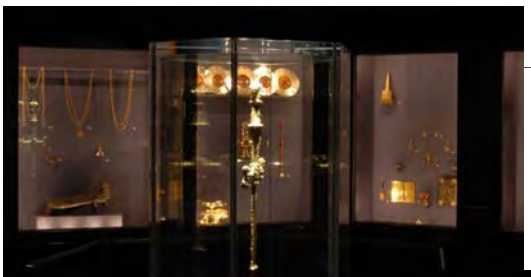
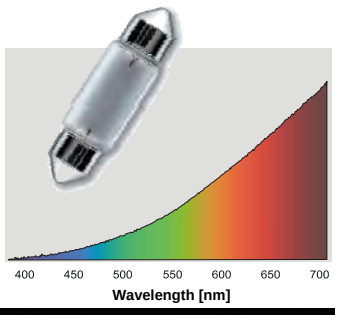
The present illumination

5 W pinol incandescent bulbs





Large amount of IR-radiation
Display cases are heated during illumination, 9-12 deg.
Causes humidity variations and deterioration of objects

Short lifetime < 1000 hours, large exchange expenses

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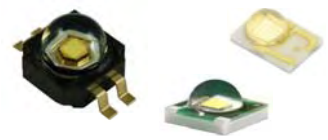
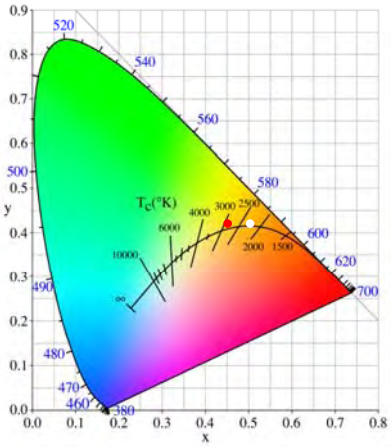
LED as an alternative



High power LEDs (~ 1-5 W, 50-200 lm)



Compact robust units with high luminous flux and high energy efficiency

Cold and neutral white LEDs
6500 – 3500 K, 104 lm/W

Warm white LEDs
3500 – 2700 K, 81 lm/W

No UV and IR-radiation
Long lifetime 20.000 – 50.000 hours, if efficiently cooled

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On-site spectral design

Visual inspection and evaluation of spectrally designed LED illumination

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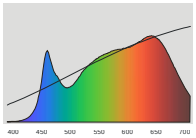
Spectral design

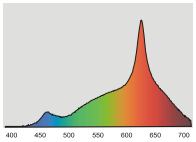
Visual inspection and evaluation of spectrally designed LED illumination

Warm white LED

CCT = 2960 K
Ra = 90

CCT = 2200 K
Ra = 95





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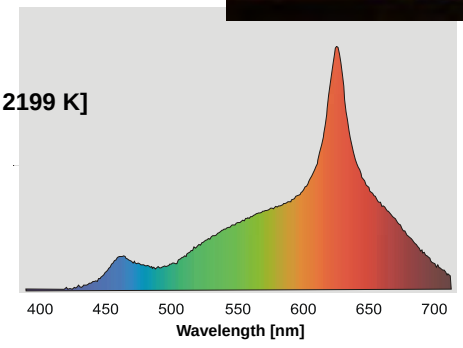
Color quality

Correlated color temperature:
CCT = 2199 K

Color rendering:

Object	Ra_i
	97.4
	99.6
	93.6
	94.9
	97.4
	96.7
	98.1
	98.7
	95.0
	97.3
	91.2
	97.7
	97.8
	94.4

CRI = 97.0
[Planckian 2199 K]



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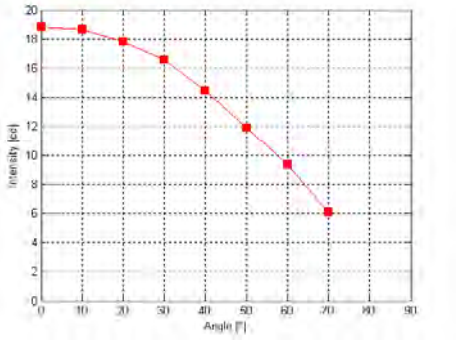
Color quality

Problems with LED color mixing using LED clusters is the appearance of colored shadows

Designed a new optical system: Mixes the light perfectly and produces diffuse light with no colored shadows

Low efficiency : 50-60 %

Measured intensity as a function of angle, close to a cosine distribution



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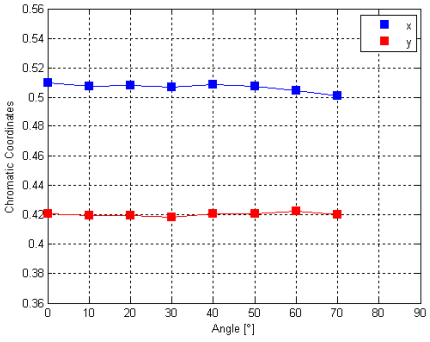
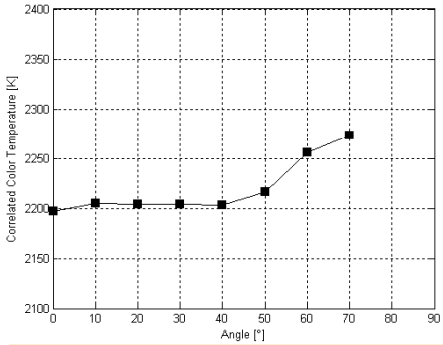
Color quality

New optical system: Investigation of the color distribution

Measured chromatic coordinates as a function of angle.





Measured correlated color temperature as a function of angle: CCT = 2200 K.

Homogeneous light quality with no colored shadows.

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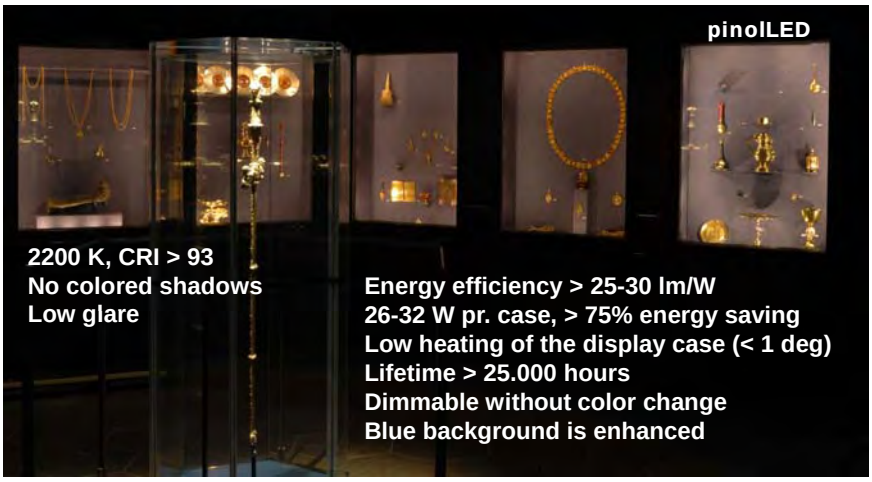
PinolLED

A new energy efficient and high quality LED illumination system



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PinolLED

LED illumination rail system

Design: Kvorning Design & Kommunikation ©

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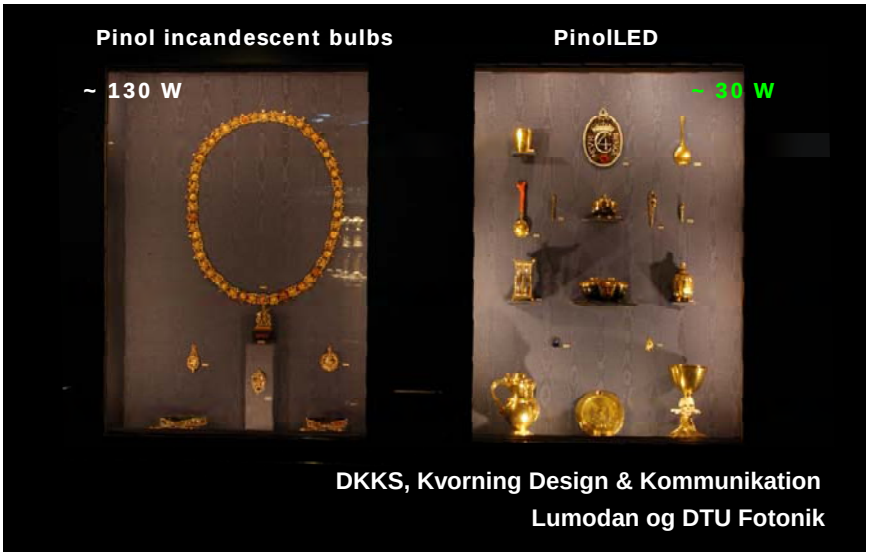

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