This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement **no 619912**

Deliverable 4.3.3

DELIVERABLE D4.433

MARKET SURVEY ON POSSIBLE LEDS TO BE APPLIED IN LED MODULE

Project Acronym	**HI-LED**
Project title	**Human-centric Intelligent LED engines for the take up of SSL in Europe**
Website	www.hi-led.eu

Collaborative project

FP7-ICT-2013-11

Start date of project: 01.12.2013

Duration: 36 months

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D4.3.3 – MARKET SURVEY ON POSSIBLE LEDS TO BE APPLIED IN LED MODULE

Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	X

Document details	
Responsible beneficiary of this Deliverable	PANNON
Work package	WP4
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Document ID	D4 4. 3 3 – Market survey on possible LEDs to be applied in LED module - HILED 619912
Release Date	30/01/2015

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List of abbreviations

CIE: International Commission on Illumination - also known as the CIE from its French title, the Commission Internationale de l´Eclairage

ISO: International Organisation for Standardization

CCT: Correlated Color Temperature

R_a: General Color rendering, expressed as a rating from 0 to 100 on the Color Rendering Index (CRI)

CRI: Color Rendering Index

CQS: Color Quality Scale

LED: Light-Emitting Diode

RGB: Additive colour model in which red, green, and blue light are added together in various ways to reproduce a broad array of colours

SPDs: Spectral power distributions

DOE: United States Department of Energy

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SECTION 1 – Context and Scope

One of the objectives of the HI-LED project is to develop a LED-based luminaire for museum lighting. To be able to select appropriate LEDs to be incorporated into the luminaire, pigments used during different epochs of European art had to be identified and their reflectance spectra had to be characterized. After this, the spectral power distribution has been optimized for paintings from different epochs of European Art. Based on these results, critical wavelength domains were identified; and LED peak wavelength regions were selected.

In this document, a market survey on possible LEDs to be built-in into the museum lighting luminaire was carried out. This work aimed not only to list the applicable LEDs with given peak wavelengths, but also make a comparison among them according to photometric properties, luminous efficacy and price.

The results of this survey are summarized in this deliverable.

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SECTION 2 – Identifying LEDs to be built-in

Optimization of spectral power distribution of light according to colour quality parameters has been done according to the pigment reflection database categorized for different art periods (see Deliverable D4.4.3.2–Specification-of-optimized-LED-SPDs-for-dominant-pigments).

Investigations based on the available pigment spectral reflection database showed that different spectral power distribution should be used for the following art periods:

- Prehistory
- Egyptian } Antiquity
- Greeks & Romans } Antiquity
- Medieval age
    - Renaissance and early modern art period
    - Industrialization & contemporary art period
- Present day

Based on these results, critical wavelength domains were identified, LED peak wavelength regions can be described as the followings:

- Blue region: 425 nm, 450 nm, 465 nm, 480 nm
- Green region: 500nm, 530 nm, 560 nm
- Red region: 600 nm, 630 nm, 670 nm

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SECTION 3 – Market survey

In the last decade LED technology has accelerated sharply, driven by the demands of general lighting market. Prices are falling quickly, possible applications are expanding, and manufacturing is becoming increasingly efficient. The technology is far from stasis, and basic research into materials and techniques is still yielding forward leaps.

In this framework, Museum lighting is not off of this trend. Lighting for art-work purposes clearly is (and will be) a niche application whose particular requirements will always justify prices a little higher than those defined for general applications. In the definition of such particularities, three parameters are specifically analysed (according to latest DOE report on Museum Lighting [1]):

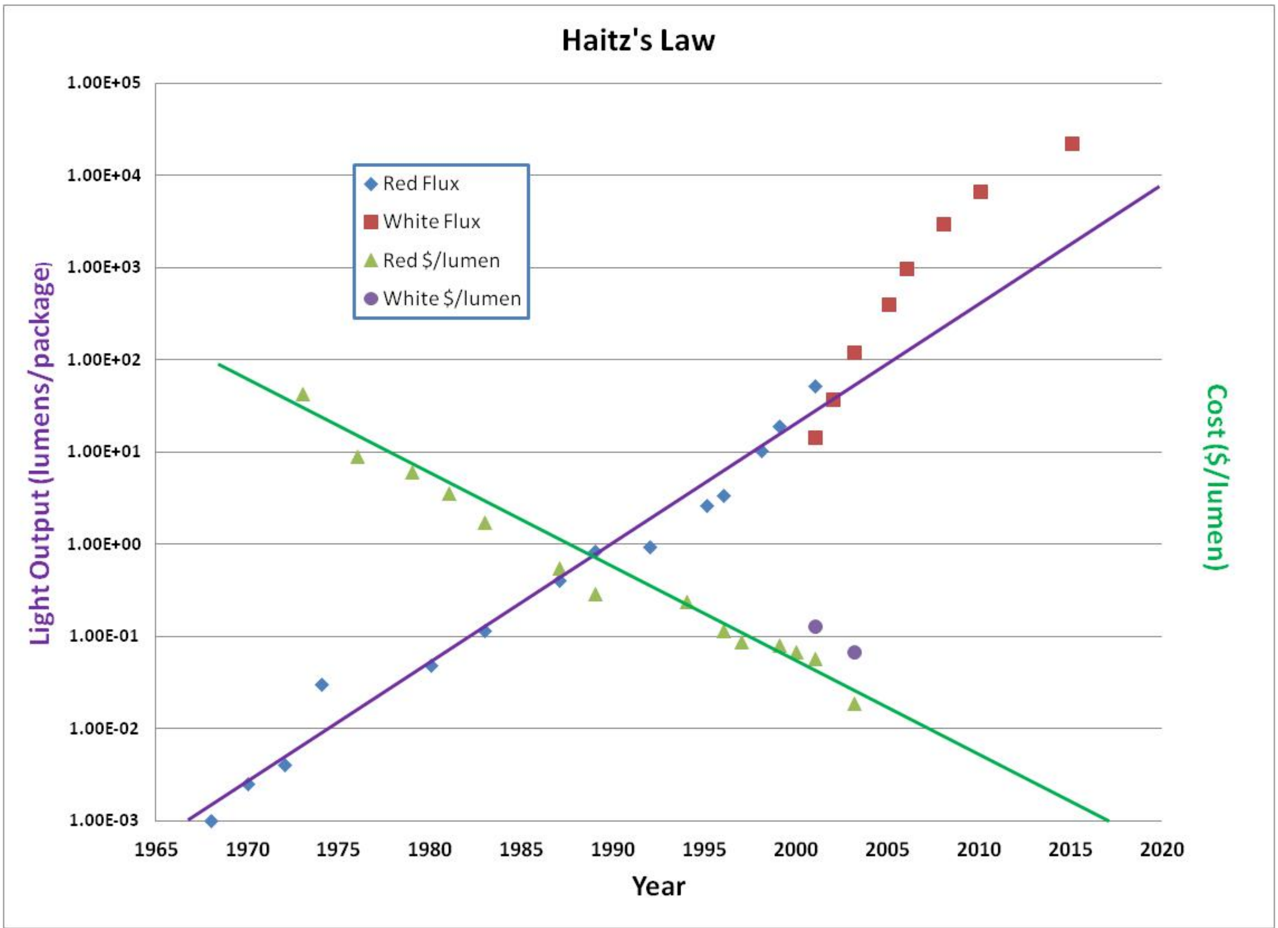

Figure 1 – Haitz's law: an observation and forecast about the steady improvement of LEDs. [2]

colour, spectral power distribution (SPD), and damage potential. Further, less significant issues are lamp efficacy, initial cost, and form factor (lamp size and shape).

Barriers to adoption of LEDs in museum lighting:

- Potential high cost, especially for dedicated LED fixtures
- Difficult selection process, due to the confusing variety of products and difficulty keeping up with rapid advancements in technology
- Technology limitations, such as poor dimming performance and potentially problematic performance of LED replacement lamps in enclosed fixtures

To address these problems, a low cost, multifunctional LED luminaire is currently under development in HI-LED project, what can meet all the requirements in the future.

Main properties of the prototype lamp:

- 10 monochromatic channels – 40 emitters
- Electrical power: 45W
- Radiant flux: 9.5W (1.6K Lumen)

There are 12 individual channels and only 10 wavelength bands: channel 7+8 (560nm) and 9+10 (600nm) are repeated twice. The reason is that each channel has a number of LEDs in series configuration. Each of the current sources that drive a channel has a maximum output voltage of 24V. This limits the number of LEDs in each series string to 24V divided by the sum of the forward voltages of the LEDs in that series string.

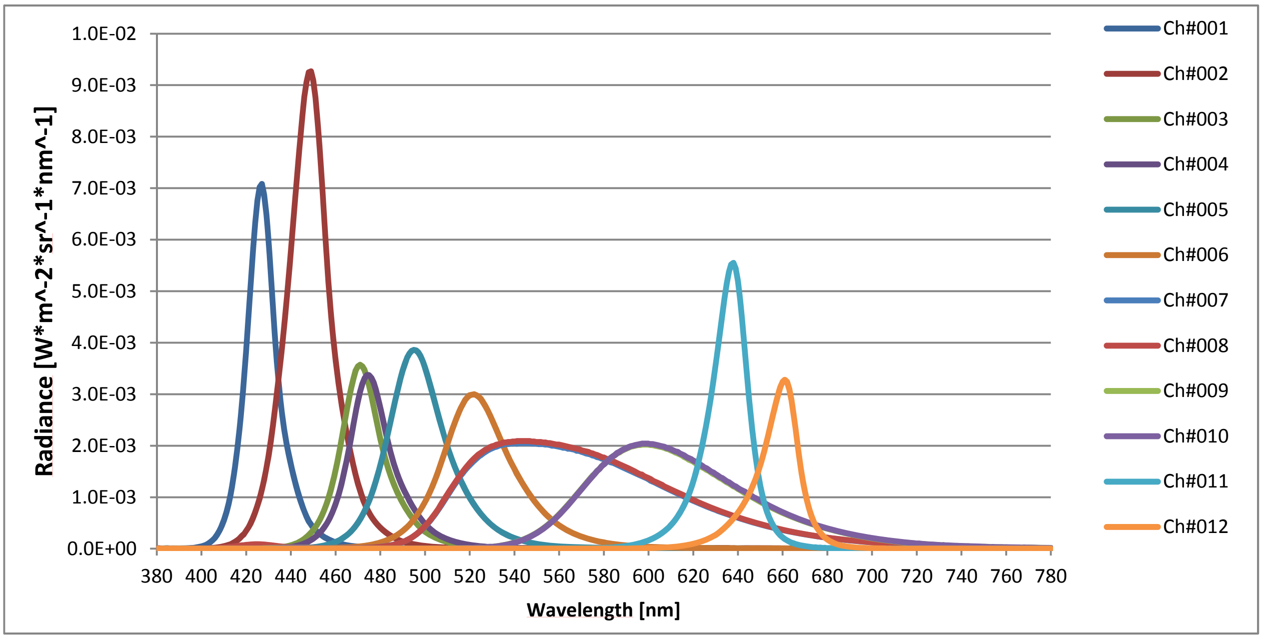

Figure 2 – Spectral power distribution of primary channels of HI-LED first prototype lamp.

Technical parameters of Philips LumiLED LEDs available at the time of development of HI-LED prototype luminaire can be seen in table 1.

Table 1 – Technical parameters [3] of Philips LumiLED LEDs 2014 available at the time of development of HI-LED prototype luminaire.

Product code	Bin code	Wavelength [nm]	Minimum luminous flux (lm) or radiometric power (mW)	Forward current (mA)	Forward voltage [V]	Viewing angle (°)	Typical efficacy (lm/W) or max wall-plug efficiency(%)	~ Unit price EUR [Digikey >2000 piece 2015 January]
LHUV-0425 -0600	/	425-430	625 mW	350	2.5-3.5	125	42 %	15.39
LXZ1-PR01	G45	445-450	550-600 mW	700	2.75-3	125	37-40%	0.94
LXZ1-PB01	A26	465-470	24-40 lm	350	3-3.25	125	21-30 lm/W	0.99
LXZ1-PB01	B46	475-480	24-40 lm	350	3-3.25	125	21-30 lm/W	0.99
LXZ1-PE01	F16	490-498	48-64 lm	350	3-3.25	125	35-44 lm/W	0.99
LXZ1-PM01	H34	530-535	103-128 lm	700	2.5-2.75	125	46-61 lm/W	0.99
LXZ1-PX01	U15	566-569	144-194 lm	350	2.5-3.5	125	107-136 lm/W	1.74
LXZ1-PL02	K-A1-5	588-592	72-104 lm	350	2.5-3.5	125	54-73 lm/W	1.59
LXZ1-PD01	D42	620-630	60-77 lm	700	2-2.25	145	38-49 lm/W	0.99
LXZ1-PA01	B62	650-660	300-350 mW	350	2-2.25	145	32-34%	0.99

Since the introduction of the first HI-LED prototype there has been a significant progress in LEDs development. By using newer generations of LEDs the achievement of better luminous efficacy is possible in 2015 (up to 10 % compared to 2014 January) and higher radiant efficiency, higher total luminous flux at same consumption level can be achieved or the same total luminous flux level can be achieved by using less number built-in LEDs, which results in lower power consumption. However this trend is not fluently true in case of currently used Philips LumiLEDs because there weren't any major improvements in the past 3 years beside the benefits of the improved manufacturing process according to manufacturer's datasheets. Philips LumiLED LUXEON Z is a portfolio of extraordinarily small, un-domed, power LEDs having peak emission from 440 nm to 670 nm. With the flexibility of this portfolio in light source engineering and optical management it is possible to create a custom design for our needs.

If the module went into production right now, with the current retail prices, today's LEDs would cost around 82 €, according with the data of Table 1. In our case, since we have purchased a relatively high quantity of LEDs (of course not as much as mass production), the actual cost of LEDs during the prototype development was 51.5 €. According to Deliverable D2.2.1 [3], if the light engines went to mass production, the cost of the LEDs would drop down to 21€, with an overall cost of LEDs-PCB-driver of 53.35€.

It can be observed in Figure 3 and Figure 4 that we have very limited space to arrange the LEDs. This determines one direction of the search.

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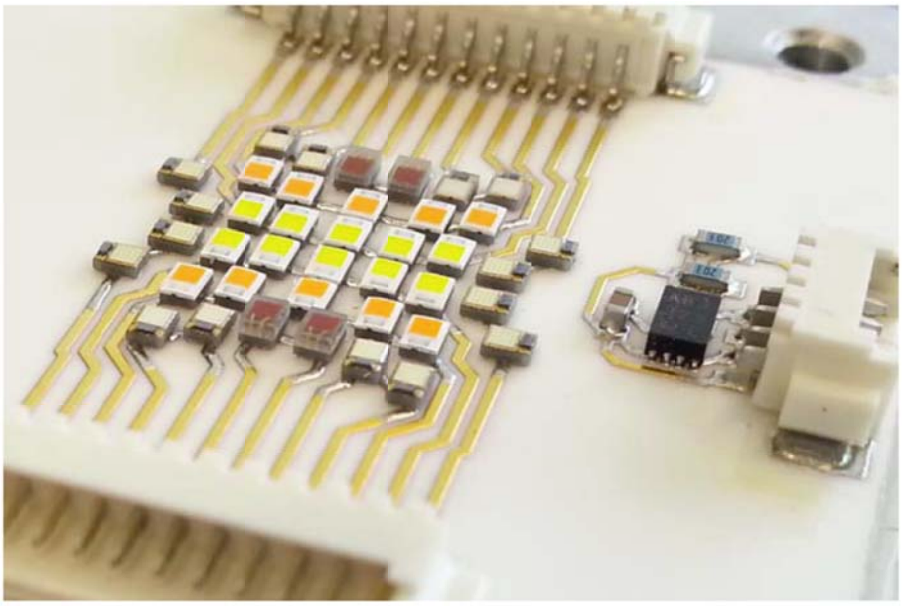

Figure 3 – Arrangement of LED chips in the prototype.

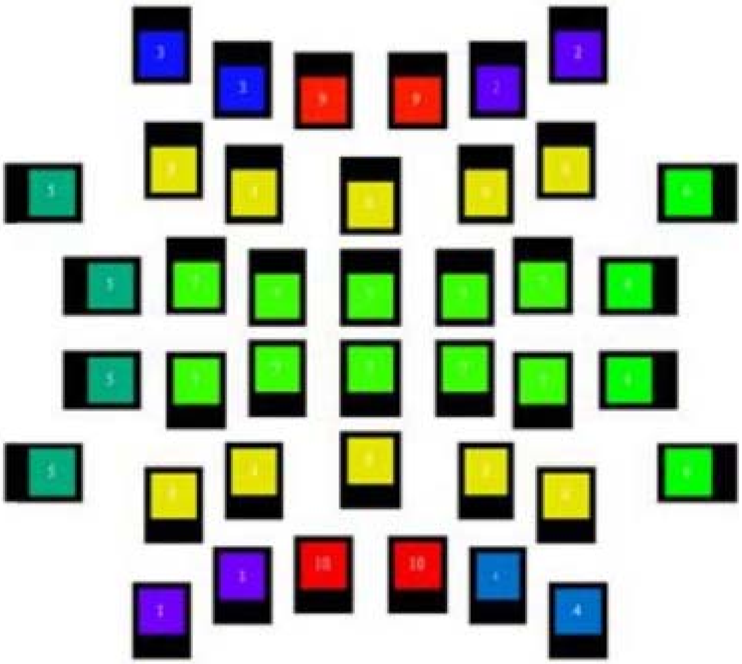

Figure 4 – Arrangement of LED chips by color in the prototype.