

Smart Lighting 2014

Intelligent & Dynamic Lighting

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New luminaire designs based on SSL systems for improving the visual harmony in the automotive sector

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Outline

- Our team and professional network
- Color Science & Technology in new cars
  - Visual harmony
  - Instrumental and visual correlation
  - Current lighting booths for visual approval
- Alternatives using SSL luminaires
  - Preliminary designs for this industry
  - Challenges to overcome
- Conclusions

The GVC-UA Team

- **Color Science & Technology:**
  - **Light, Matter, Eye and Visual Perception**
  - **Measurement, appearance and color matching**



- **5 PhD**
  - **4 Physics**
  - **1 Industrial Eng.**
- **3 PhD students**
  - **1 Textile Eng.**
  - **2 Materials Eng.**

Our professional networking

- **Consortium CD6-UPC + GVC-UA**
  - **CD6: Centre for Sensors, Instruments and Systems Development (Terrassa, Barcelona)**
  - **Leader: Dr. Jaume Pujol**



- **MSc degree in Color Technology for the Automotive Sector (edition 2014 – 15)**
  - **Industrial partners (internships, etc)**

MASTER in COLOR TECHNOLOGY for the AUTOMOTIVE SECTOR
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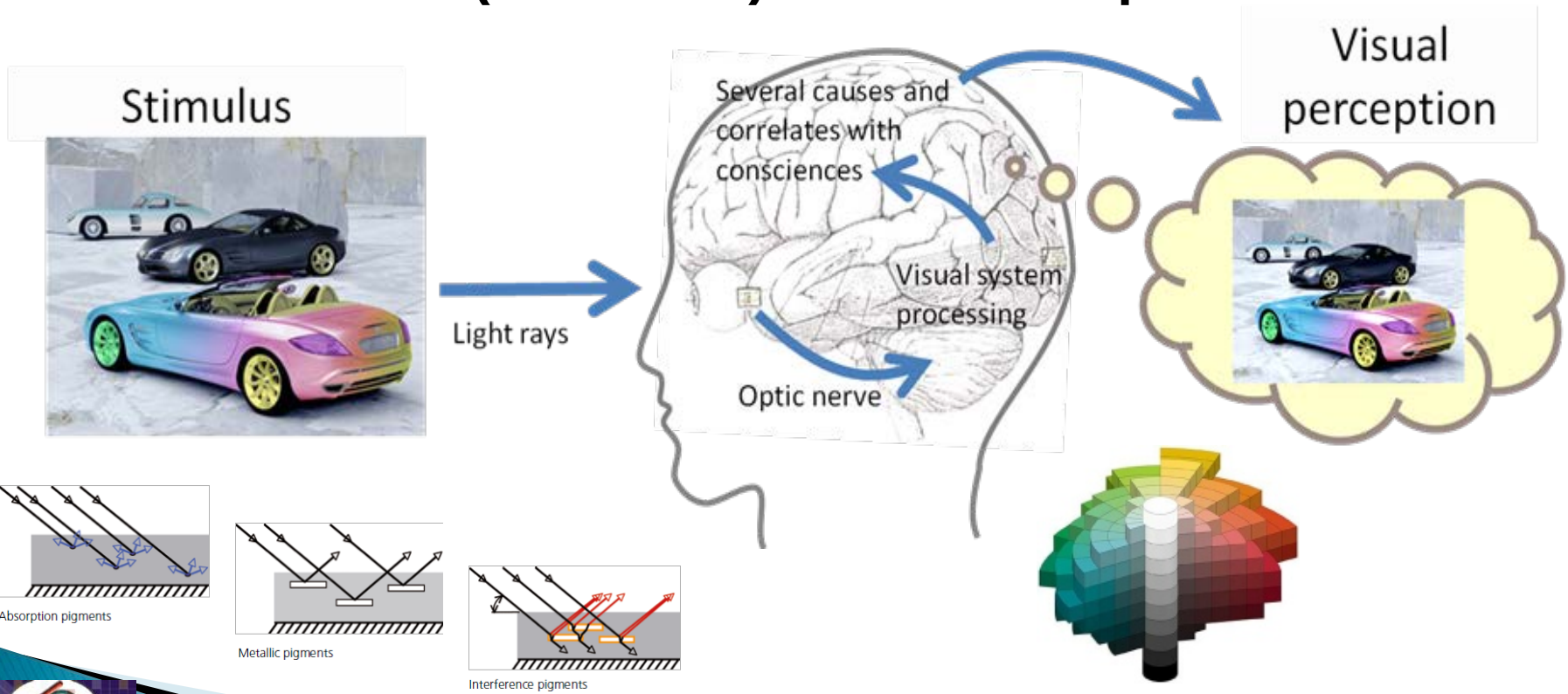
Smart Lighting 2014 Intelligent & Dynamic Lighting

Color Science & Technology

- **Pigments with goniochromatic effect**
  - **Light – Matter – Eye interaction**
  - **Nano/micro (structural) ⇒ macroscopic scales**



Visual Harmony in New Cars

- **We are not talking about:**
  - **Exterior lighting design**
  - **Interior / ambience lighting design**





- **It is about visual inspection & approval:**
  - **Car body and its interior (dashboard, seats, etc)**
  - **The new car should look as if all parts were painted together.**







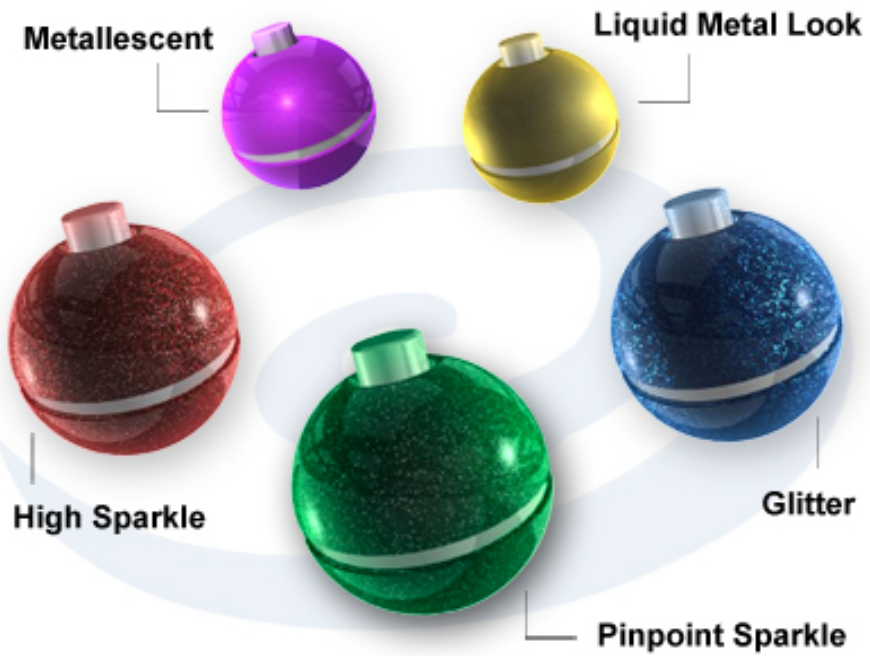




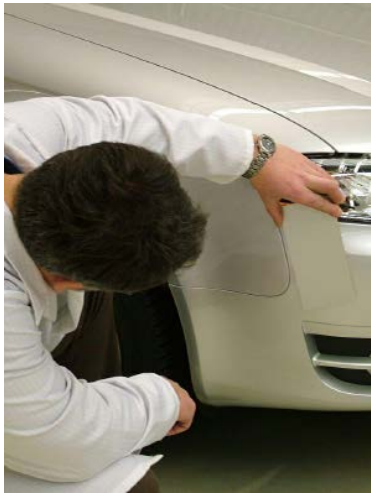
Visual Harmony in New Cars

- Colored materials with **different** pigments to obtain the **same** visual effect of color & texture











Visual & Instrumental Correlation

- Numerous add-on-parts for car bodies
- Different substrates, suppliers, types of coatings, applications, etc.
- In quality control, paint shop and assembly

- Color & Texture measurements using advanced optical instruments for visual reproducibility:
  - Color standards (references)
  - AUDI2000 color-difference formula based on CIE-L*a*b* model
  - Texture and color tolerances for total visual approval
  - Challenge: to assure color harmony in many points of view

Visual & Instrumental Correlation

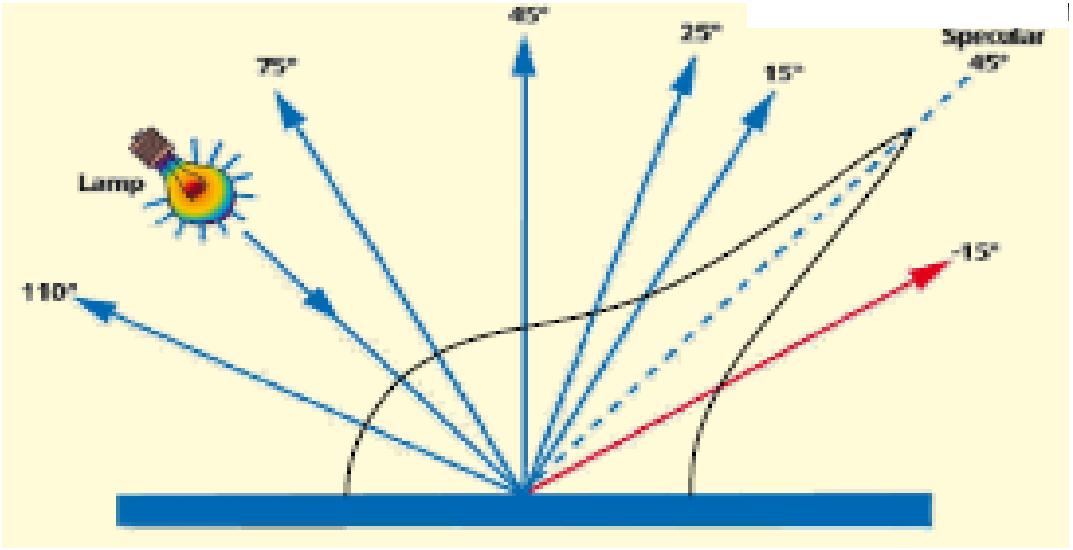
Multi-angle spectrophotometers





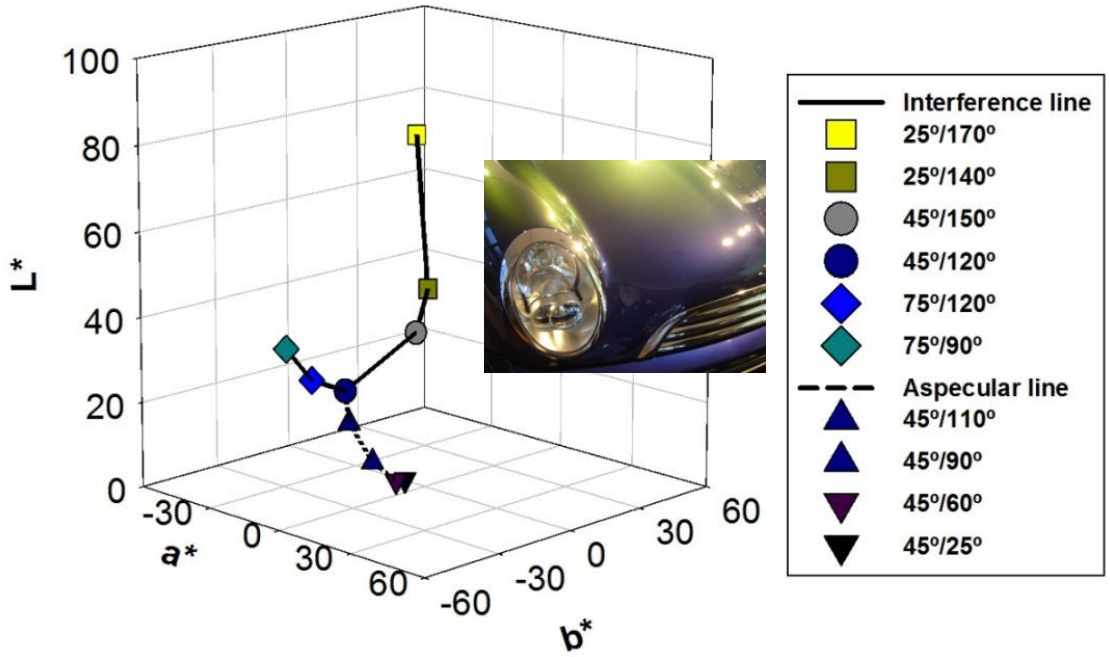




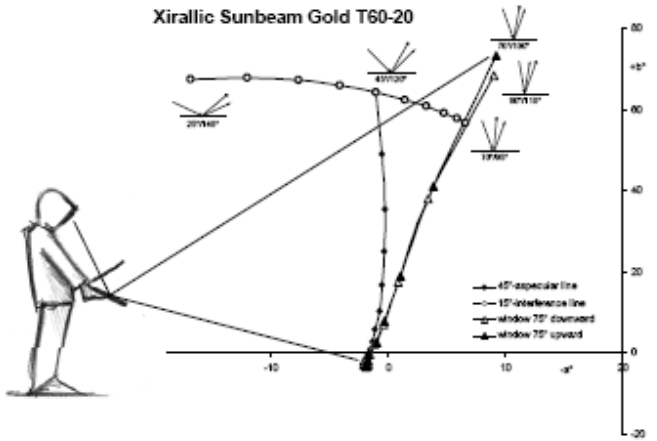


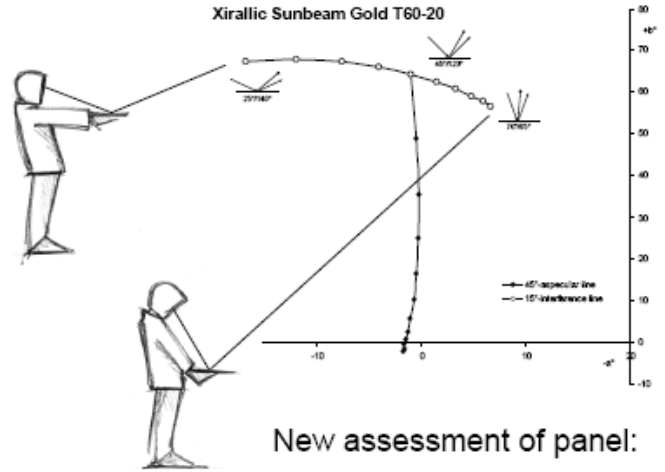
Standards	ASTM interference line						ASTM/DIN aspecular line			
illumination angle	25º	25º	45º	45º	75º	75º	45º	45º	45º	45º
observation angle	170º (-15º)	140º (+15º)	150º (-15º)	120º (+15º)	120º (-15º)	90º (+15º)	110º (+25º)	90º (+45º)	60º (+75º)	25º (+110º)

Visual & Instrumental Correlation



- **<u>Variable</u> color according to directions of <u>light incidence</u> and <u>viewing</u> position**





New assessment of panel:
Moving panel parallel up and down.

Visual & Instrumental Correlation

- Lighting booths used in the automotive sector
  - Diffuse illumination
  - Directional illumination and some viewing directions
  - All based on fluorescent lamps (D65 simulators, etc.)
    - Panels, isolated add-on-parts, and complete cars



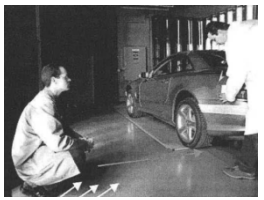
SpectraLight III (OP 1)



Byko-spectra Effect (OP 2a)







Forchheim und Willing cabinet (OP 2b)



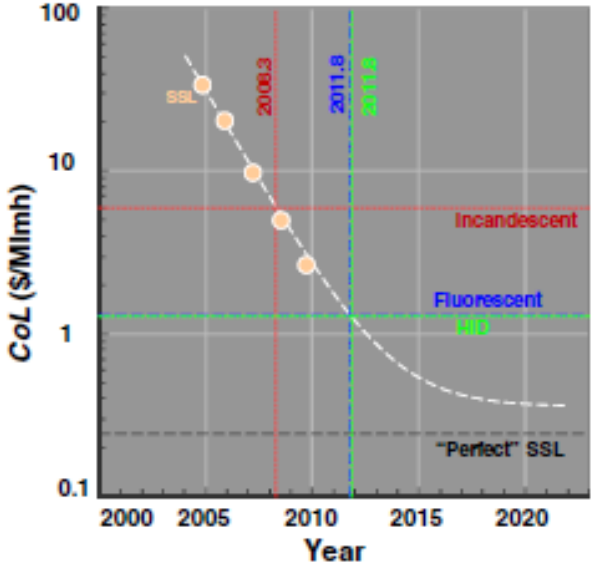
OLIGO Lichttechnik (OP 3)

Balance of lighting cabinets

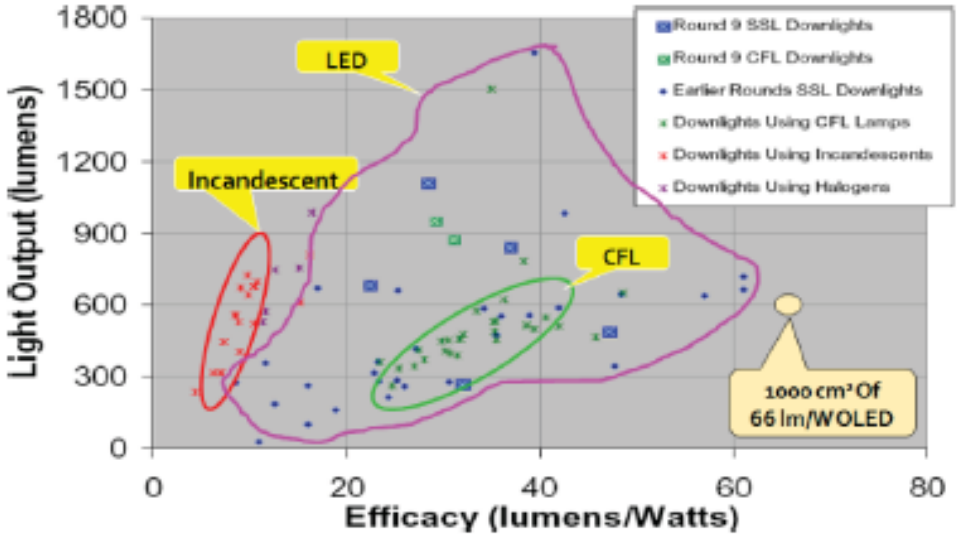
TECHNICAL KEY FACTOR	OP 1	OP 2ab	OP 3
Diffuse illumination	YES	NO	YES
Directional illumination	NO	YES	NO
Metamerism detection	YES	NO	YES
Uniform horizontal illumination	YES	YES (b)	YES
Uniform vertical illumination	NO	YES (b)	YES
Sparkle / glitter evaluation	NO	NO, except (a)	NO
Gonio-instrumental vs. visual assessment correlation	NO	YES	NO
Energy efficiency	↓↓	↓↓↓ , mainly (b)	↓↓
Maintenance	↑↑↑	↑↑↑	↑↑↑
Installation cost	~ 100 k€	~ 200 k€	~ 300 k€

Alternative SSL solutions

- **Many technical advantages:**
  - **Evolution of energy efficiency and costs**
  - **New technologies (wOLED, quantum dots, etc)**
  - **Small light sources, easily shaped in many luminaires**



Solid-state lighting: an energy-economics perspective (2010)



Organic light-emitting-diode lighting overview (2011)

Alternative SSL solutions

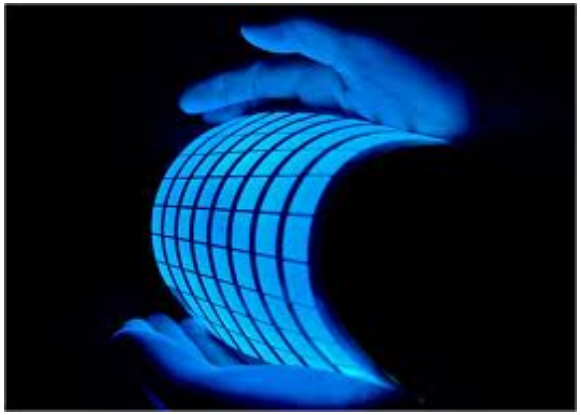
- Preliminary luminaire designs for automotive

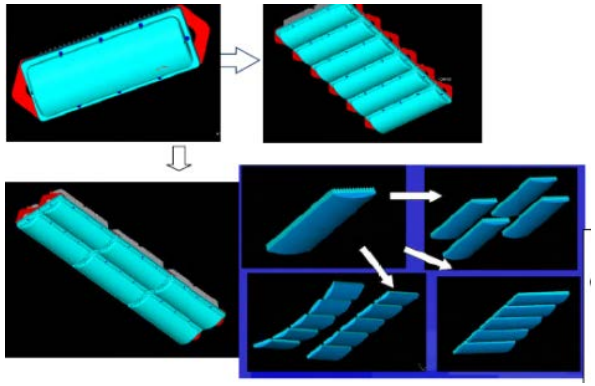












Can we do it?

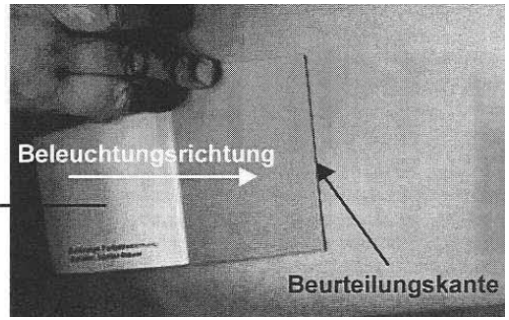
Alternative SSL solutions

- **Challenges to overcome (I)**
  - **Sufficient space for complete cars and interior/exterior parts**
  - **Standard measurement geometries**
    - **Diffuse illumination interchangeable with directional**
    - **Complementary directional illumination for sparkle/glitter**



  - **Able to use a tele-spectroradiometer for instrumental measurement as complementary way in the same position/direction as the color expert eye;**



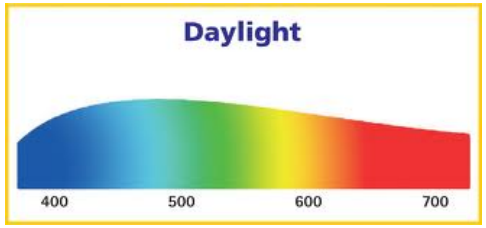


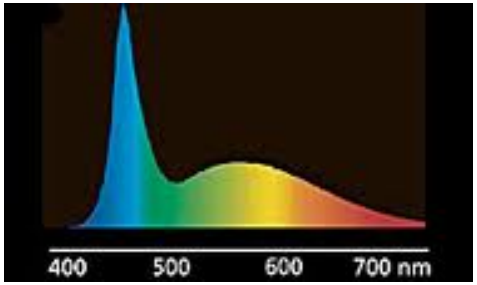


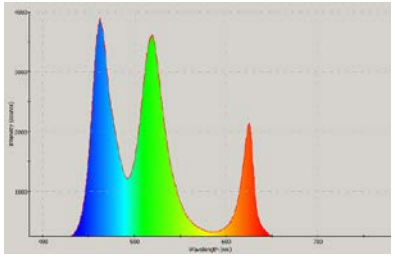
  - **<u>Variable</u> illuminance levels, and high color rendering (D65, F11)**

Alternative SSL solutions

- **Challenges to overcome (II): color rendering**
  - **White LEDs or OLEDs for spectrally reproducing D65??**







  - **Current options:**
    - **Varying new compounds in SSL sources**
    - **Color filtering of SSL luminaire covering (CD6-UPC + GVC-UA)**
    - **Additive mixing of mono-chromatic LEDs with white LEDs**
    - **Additive mixing of mono-chromatic LEDs (CD6-UPC + GVC-UA)**

Luminescence properties of YAG-Ce, Gd phosphors synthetized under vacuum condition and their white LED performances (2014)

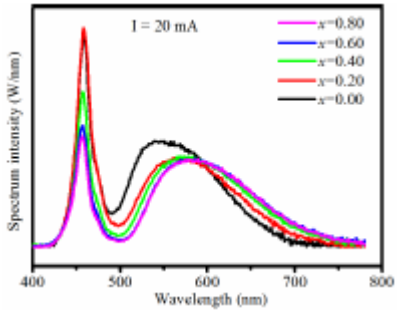


Table 1. Optical properties of white LEDs using modified $(Y_{0.96-x}Gd_x)_3Al_5O_{12}:Ce_{0.06}$ phosphors

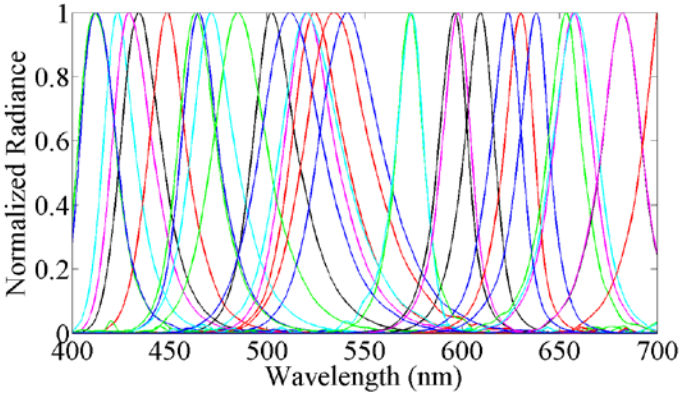
Gd^{3+} content x (mol)	CIE color coordinates X	Y	Luminous efficiency (lm/W)	Ra	CCT(K)
0.00	0.3177	0.3573	134	73	6112
0.20	0.3293	0.3173	109	82	5656
0.40	0.3734	0.3470	106	76	3966
0.60	0.3973	0.3524	96	72	3338
0.80	0.4055	0.3613	95	70	3231

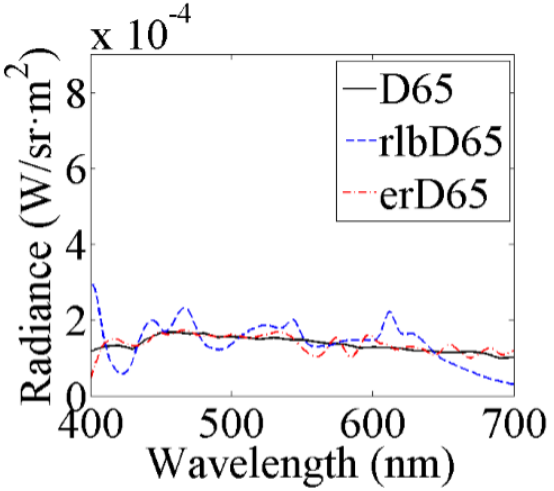
Alternative SSL solutions

- **Additive mixing of 31 mono-chromatic LEDs**
  - **Spanish Patent P201330951 (2013) by UPC and UA (er)**



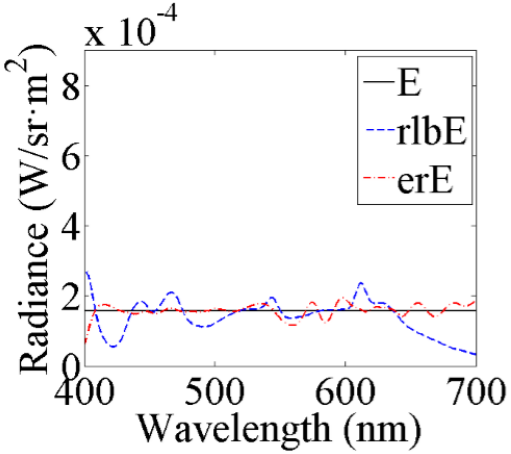


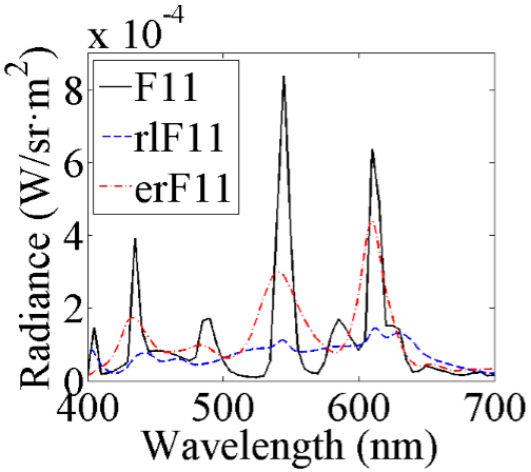






US2011/0062873 A1 (rlb)





Alternative SSL solutions

- **Additive mixing of 31 mono-chromatic LEDs**
  - **Spanish Patent P201330951 (2013) by UPC and UA (er)**

		CCT	R_a	R_b	x	y	ΔE_{ab}	GFC	RMSE
CIE	D65	6500	100		0.3127	0.3293	-	-	-
	E	5550	100		0.3333	0.3333	-	-	-
	F11	4000	83		0.3805	0.3769	-	-	-
rlb	D65	5960	95.9	95.21	0.3288	0.3360	0.04	0.9544	4.56E-3
	E	5086	95.0	94.44	0.3418	0.3378	0.03	0.9416	5.31E-3
	F11	3838	96.1	94.22	0.3875	0.3799	0.18	0.7145	1.00E-2
er	D65	6472	94.7	93.20	0.3138	0.3259	0.02	0.9939	1.53E-3
	E	5321	91.5	88.86	0.3362	0.3330	0.02	0.9934	1.82E-3
	F11	4122	85.0	77.02	0.3786	0.3870	0.08	0.8241	1.03E-2

Conclusions

- **Visual harmony management of automotive coatings based on special-effect pigments, and its implementation by standards (CIE, ASTM, etc.), is still highly dependent on fluorescent lamps.**

- **But, SSL technologies can provide gradually new alternatives for this worldwide industry, breaking some challenges related to the spectral matching for the D65 and E illuminants.**

- **GVC-UA + CD6-UPC can provide high-added value collaborating with large lighting companies for reducing costs, and improving energy efficiency and visual harmony.**

Acknowledgements

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