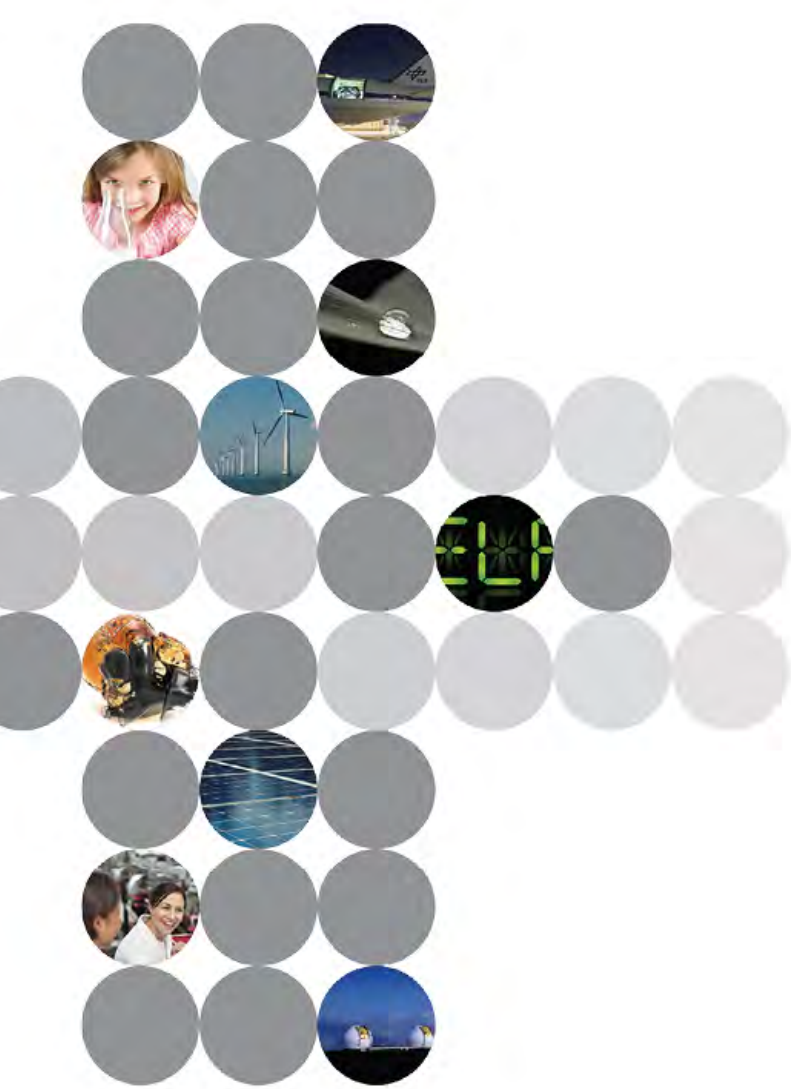


Large Area
Intelligent
Efficient
High Quality
Solid-state
Lighting

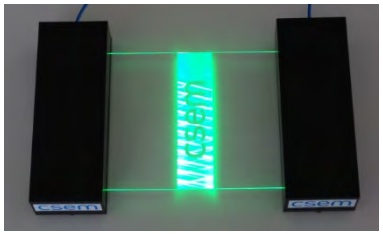
LASSIE-FP7

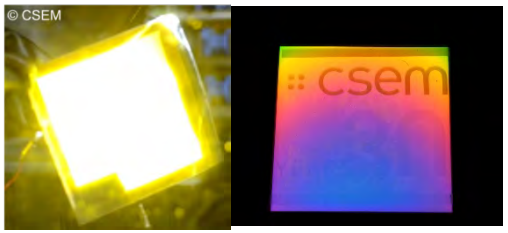
Highlights

Rolando Ferrini
rolando.ferrini@csem.ch

Outline

- Thin large area solid-state lighting modules
- The technological background
  - LEDs
  - OLEDs





- LASSIE-FP7: Highlights (*http://lassie-fp7.eu*)

Thin large area solid-state lighting modules

- **Why large-area?**
  - Light distribution over a large area
  - Reduced intensity → Reduced glare
  - Reduced luminaire losses

- **Why thin?**
  - Aesthetics
  - Design
  - Weight & Space

- **Which technologies?**
  - OLEDs
  - LEDs

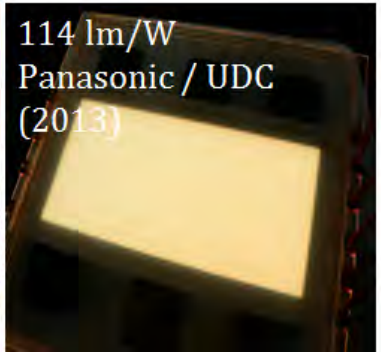
Fluorescent troffer (with Louvers)

LED panel

Efficiency

LEDs

OLEDs

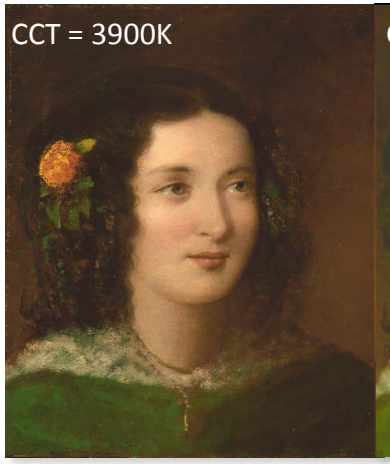


156 lm/W
NEC / Yamagata Univ.
(2013)

NEC

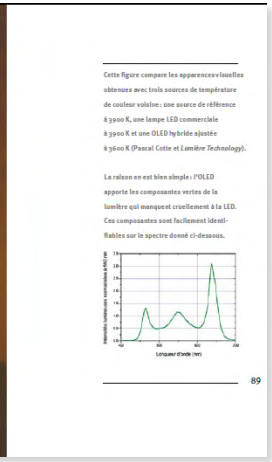
Lighting quality

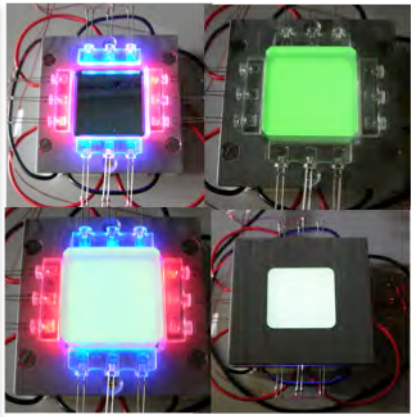
Black body



Philips NR63

Hybrid OLED

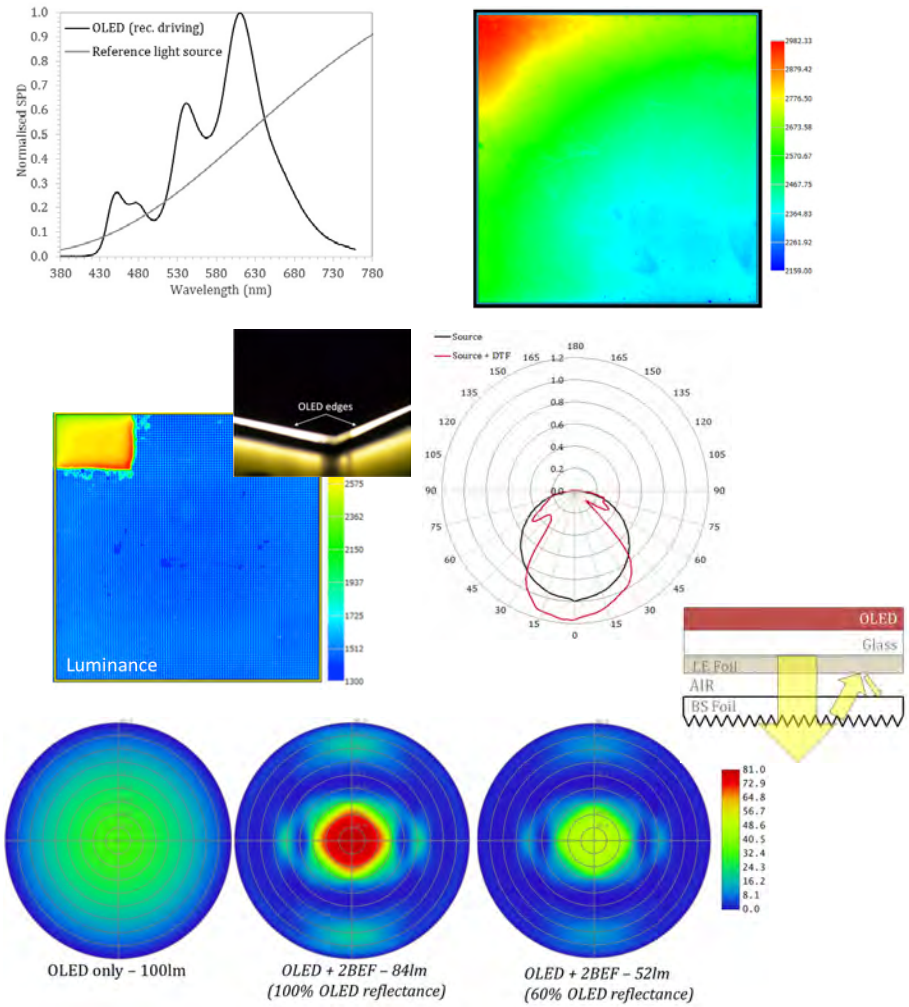




M. Schaer, P. Cotte, L.Zuppiroli (*Lumières du Futur*, PPUR, 2011)

We need a new definition and measure of lighting quality beyond CRI based on the whole source spectral characteristics of SSL sources

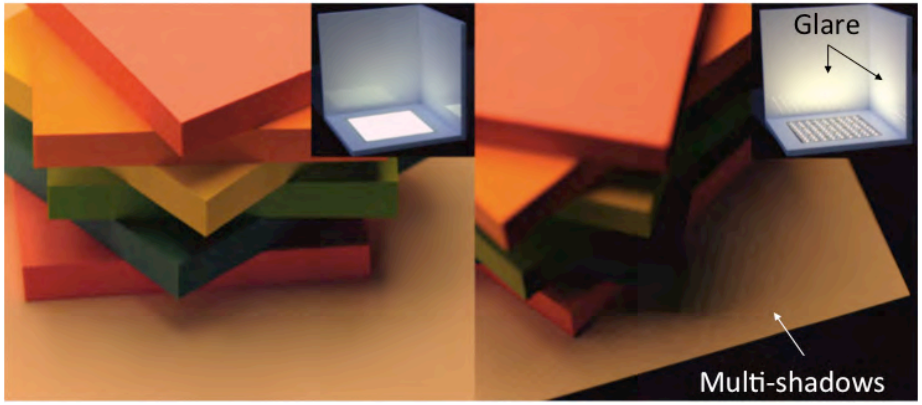
LEDs vs. OLEDs



- High color rendering
  - ... but de-saturates red colors (e.g. skin tones)
- Modest to good luminance uniformity
  - ... but slow variatons
- Large optical losses (e.g. light trapping in glass modes)
  - ... but with out-coupling foils > 50% improvement
- Low efficiecy de-glaring solutions
  - ... due to poor light recycling
- Difficult beam shaping
  - ... OLEDs are large area lambertian emitters

LEDs vs. OLEDs

- Possible medium to high color rendering
  - … but with increasing price and/or complexity
- High luminous intensity
  - … but “hot spots” can be an issue
- Possible limited lumen output / chip
  - … but LED arrays can provide enough lumens
- Small source dimensions (i.e. point sources)
  - … ~1mm^2 *vs* 10^{4}mm^2
- Lambertian point sources
  - … bright spots, multi-shadows, glare, etc.



Commercial LED & OLED lighting modules

	LEDs		OLEDs	
	Philips *Highest lumen output*[1]	OLEDworks (Philips)	LG Chem *Largest Area*	LG Chem *Highest Efficacy*
Best commercial module	Fortimo LED DLM 5000 55W/830 Gen5	Lumiblade Brite FL300	N6SD30	N8SA30
Emissive area (mm²)	2'940 [2]	102x102	320x320	100x100
Thickness (mm)	~~43.6~~ [2]	~~3.0~~ [1]	1.0[1]	~~1.97~~[1]
Luminous flux (lm)	4'500-5'500	300 [2]	800-1'200[2]	75
Lumen Efficacy (lm/W)	~~100~~[3] 79[4]	>50 [3]	60	80
CCT (K)	3'000	3'000 [4]	3'000	3'000
CRI	>80	>80	>90	>80
Lifetime – LT70 (10^3 hrs)	50	10 [5] 50 [6]	40 [3,4]	50[2]
Price / unit	69 EUR[5]	136 EUR 60 EUR [7]	600 EUR[5]	82 EUR[3]
	[1] Other products exist with lower lm [2] Based on the technical drawings [3] Module [4] System [5] eBay (source)	[1] Including thermal backplate, housing and wiring [2] At 340mA and 19V [3] At 300 lumen [4] 4000K planned [5] At 300 lumen [6] At 125 lumen [7] For orders above 40 OLEDs	[1] Bare OLED [2] At 1700mA / 8.5V (OLED-info) [3] At 3'000 cd/m2 [4] Using LG proprietary "Face Seal" technology [5] OLED-info 29.01.15 (680 USD)	[1] With housing and wiring [2] Initial luminance not specified [3] Source

Commercial LED & OLED lighting modules

Luminous flux (lm/EUR):
LEDs >> OLEDs
(> x50)

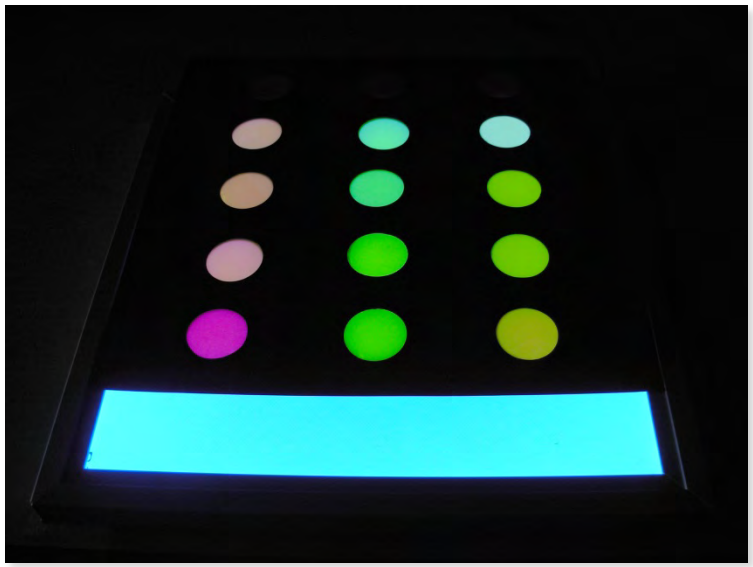
In order to have a better cost-performance for OLEDs:

- Reduce manufacturing costs
  - … the OLED display industry may help
- Increase the emitting area
  - … but reduces yield & transport/handling/cleaning issues
- Increase the lumen output:
  - … but performance decrease and glare

How to improve the quality of LED lighting?

CTI Project « New Color-changing films for lighting applications » (nr. 8184.1 EPRP-IW)

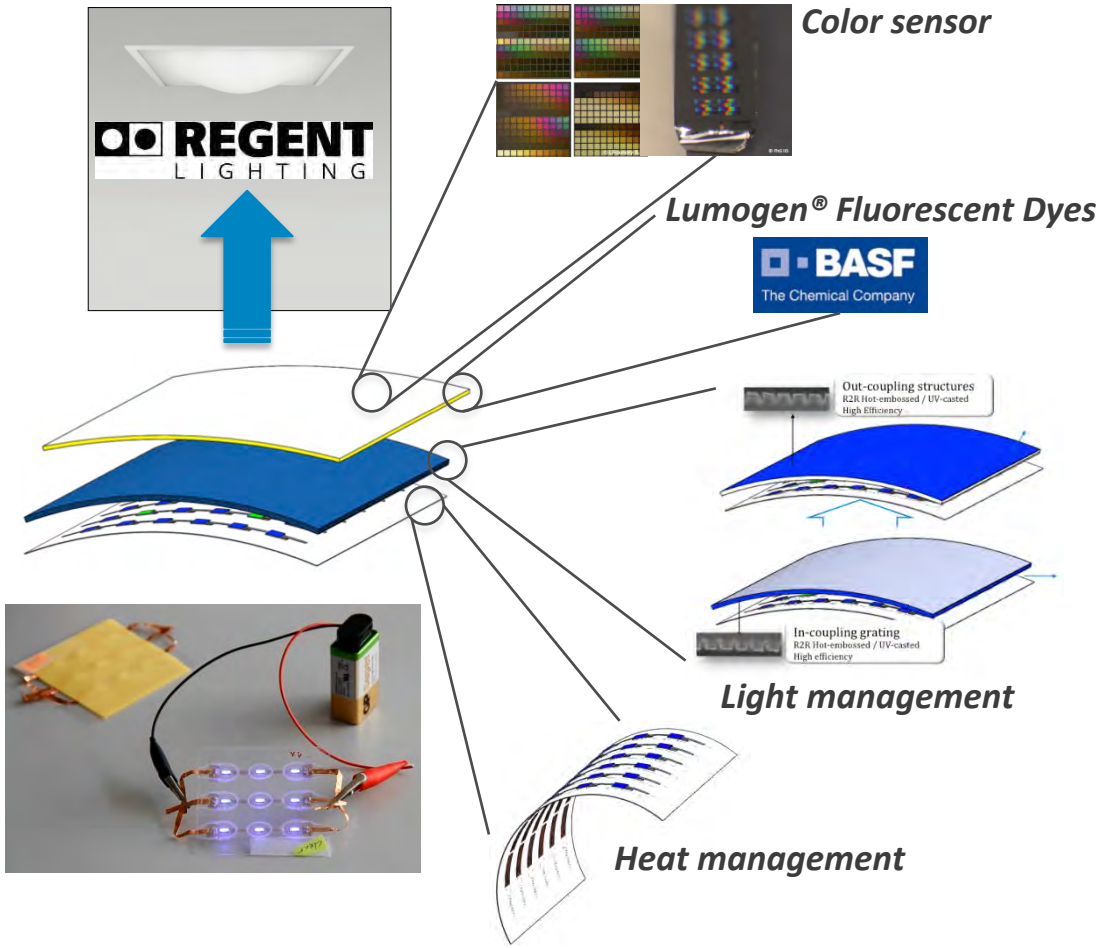
2006-2008

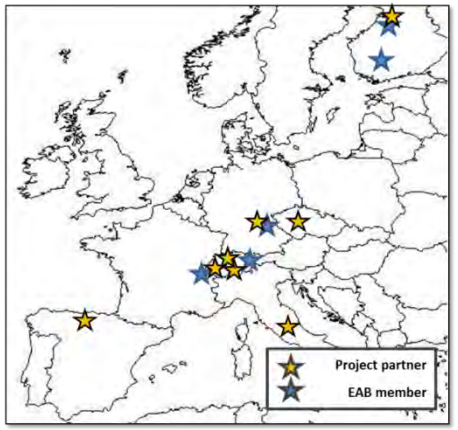


Patents

- EP08164280.3 & US 2010/0102251
- US 13/114.558 & PCT/IB2012/052577

The « hybrid » solution: (O)LED modules





Property of the LASSIE-FP7 Consortium

Large area LED modules

Edge-lit

- Thin form factor (T ≤ 9mm)
- Thick & heavy light guide
  - Not compatible with R2R production
- Moderate luminance uniformity
- Color shift across the emitting area
- Low efficiency

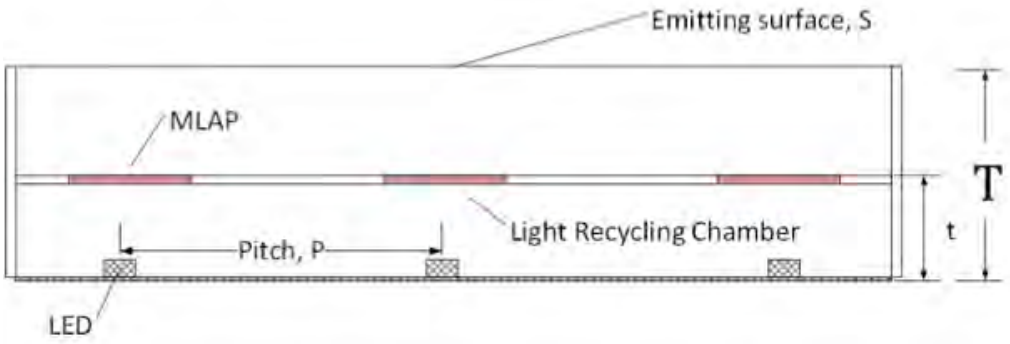
9mm
3'100lm
80lm/W
3.800 Kg

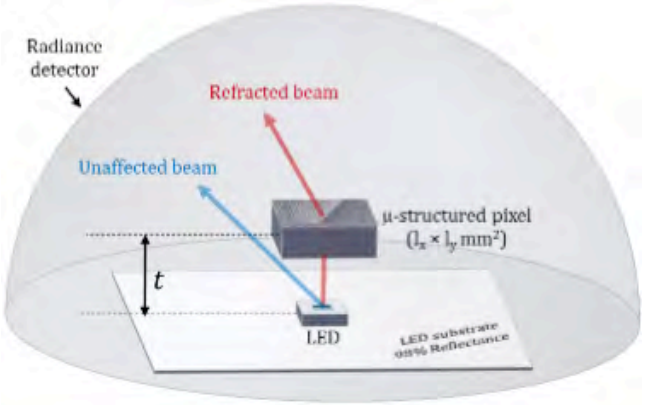
Direct-lit

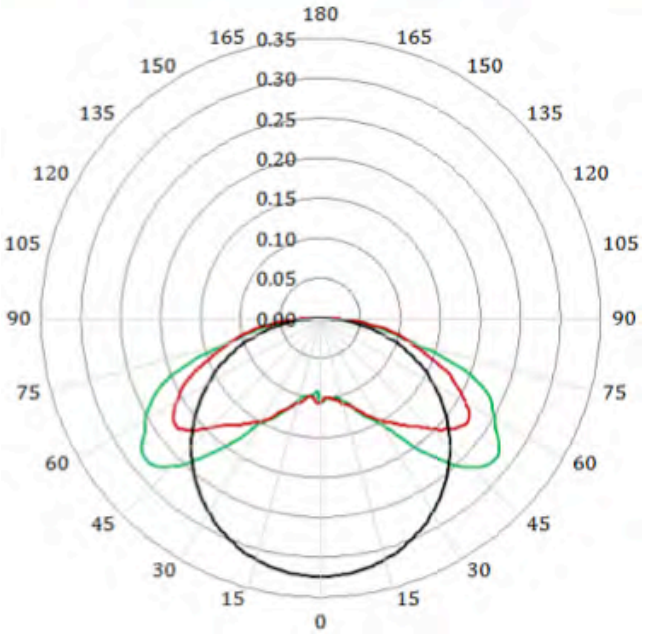
- High uniformity (diffusers)
  - … but the rule-of-thumb is $T \geq P$
- Thinner form factors are possible
  - … but with reduced pitch, i.e. higher costs
- High lumen output & efficiency
- Very large emitting areas are possible
- Potentially low weight
  - … with the use of thin-film/on-foil optics

87mm
5'100lm
122lm/W
3.250 Kg

Beam-shaping « bat-wing » foils





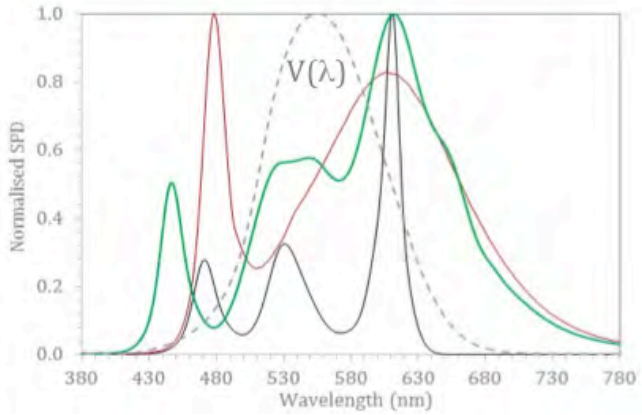


- Pixels of periodic μ-structures (MLAPs)
- Narrow-angle rays: widely deflected off-axis
- Wide-angle rays: unaffected
- On-foil technology

High quality lighting: Color-Changing Foils (CCFs)

- *RGB spectra tuned to V(λ)*: High luminous efficacy but poor color rendition
- *Inorganic phosphors*: Improved color rendition with lower luminous efficacy
- ***CCFs technology***: **Excellent color rendition with acceptable luminous efficacy**
  - Efficient phosphors → Low concentrations
  - Co-extruded into thin-films → Roll-to-roll production

	u'	v'	Δu'v'	CCT	LER	CRI	R9
RGB	0.2508	0.5214	0.0001	2'995	379	74	-16
B+yellow	0.2507	0.5214	0.0001	2'999	289	80	41
B+CCF	0.2506	0.5213	0.0001	2'999	307	92	51



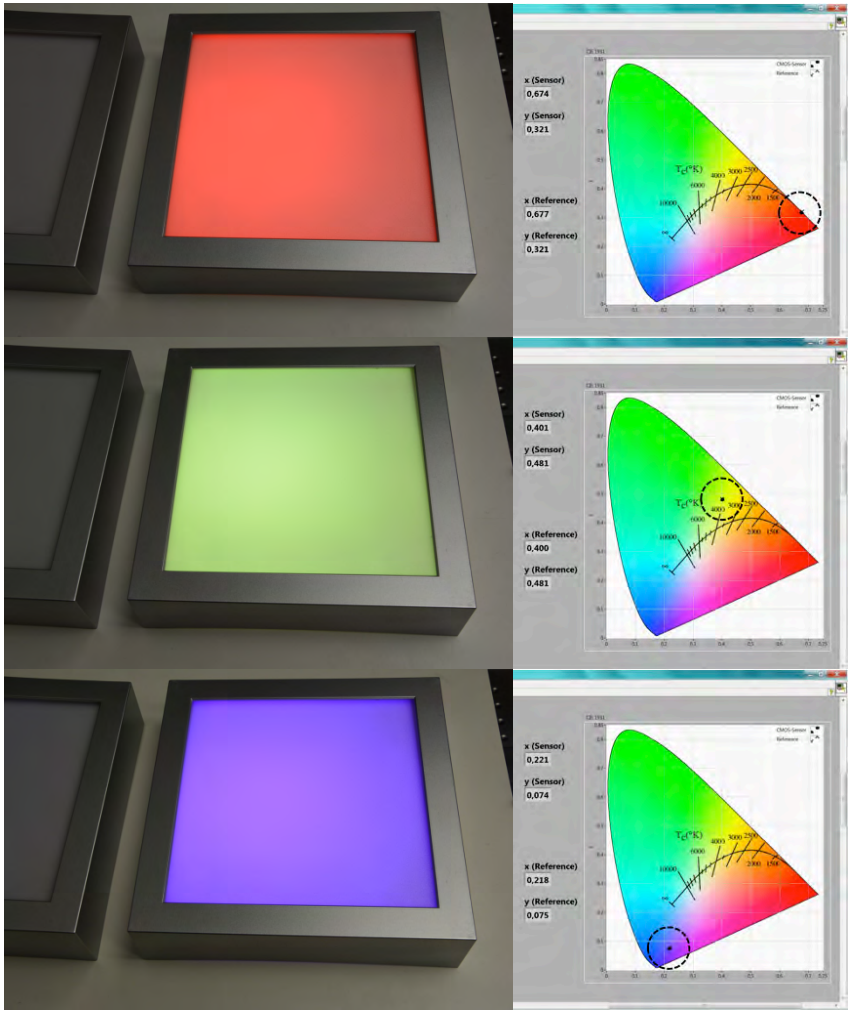
Intelligence: Colour feed-back

Intelligent luminaires require colour feed-back

- Compensate for any drift of light output (e.g. ageing)
  - Chromaticity point
  - Color rendering
- Accurate colour-sensing feedback
- Cost-effective colour multispectral sensors

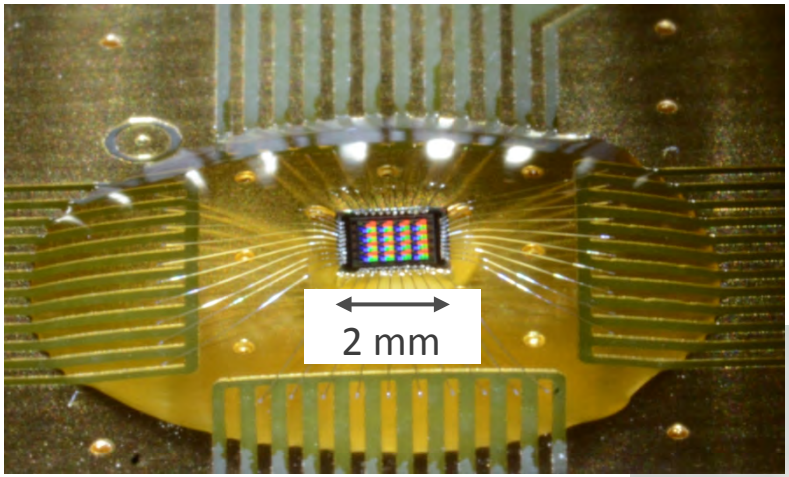
Targeted solution

- ✧ 16 CMOS photodiodes with different filters
- ✧ Up to 16 spectral channels

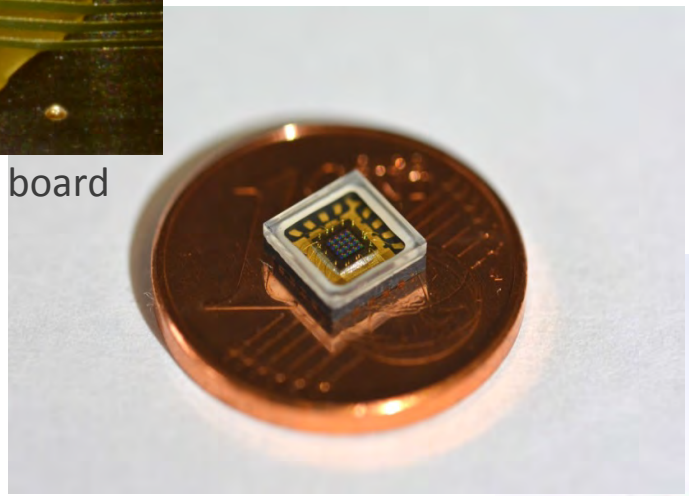


Courtesy of FhG IIS

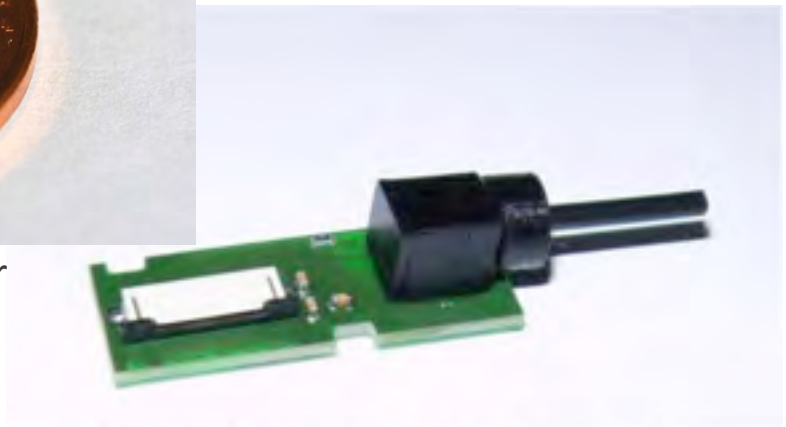
Sensor integration



Sensor chip wire-bonded on test board



Packaged sensor

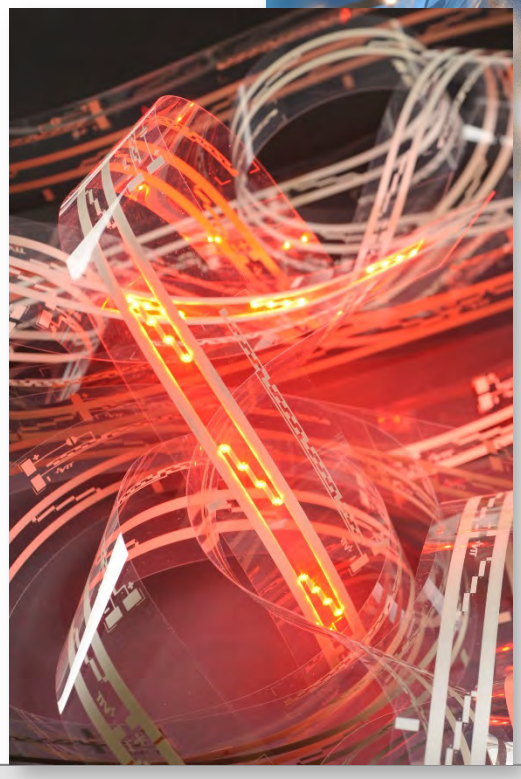


Sensor board with fiber coupling

LED-based polymer foils

Opportunities

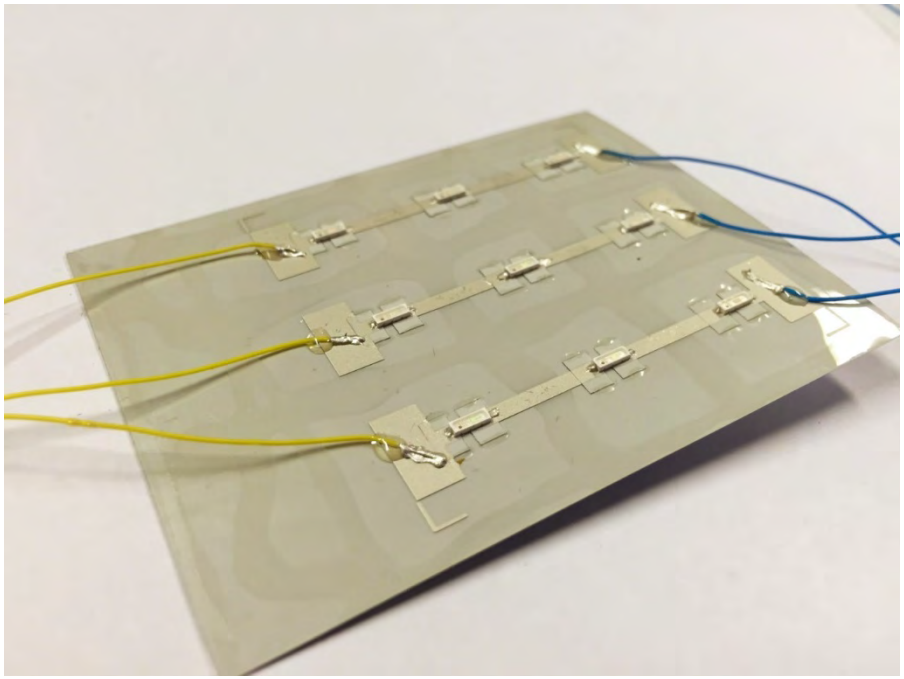
- LED-based polymer foils ➔ Flexible lighting modules
- Printing and assembly with R2R processes
- Improved performance:
  - Optimized electronics layout
  - Traditional electronic SMD components
  - Bare LEDs with no on-chip optics

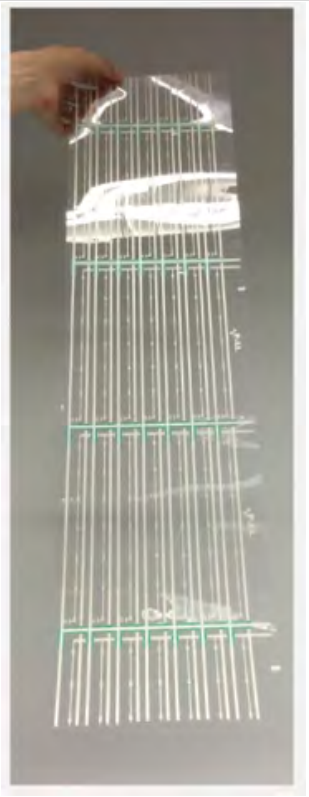


Challenges

- Heat management
  - Poor thermal conductivity of the polymer foils

Heat management : Final solution & LED foils





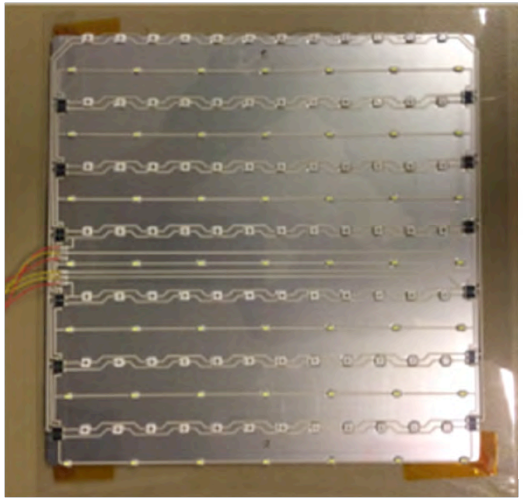
Heat management slugs

- Thermal resistance: 2°C/W (module) to 0.2°C/W (luminaire)
- Roll-to-Roll compatible processes

R2R LED foil

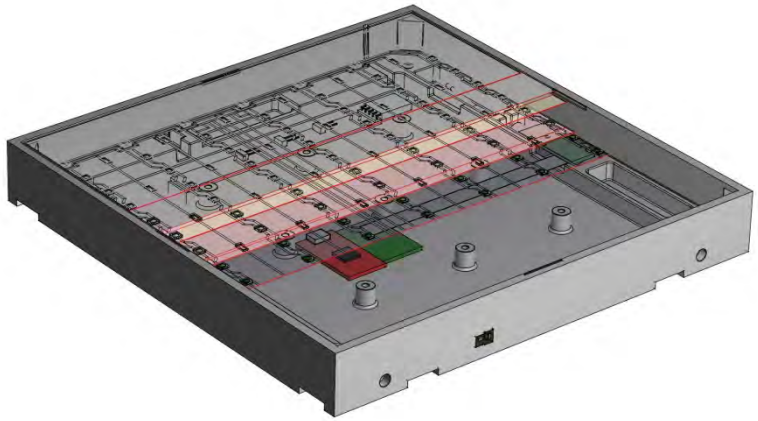
- 200 mm x 600 mm
- Possible to integrate with CCFs

Module integration

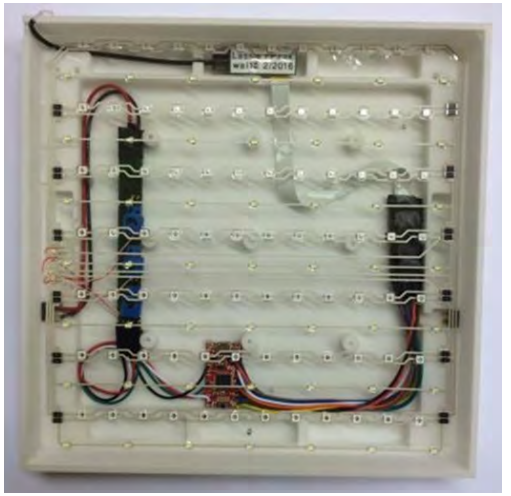


LED foil assembly

- 49 white LEDs (heat mngt.)
- 84 monochromatic LEDs



Lighting module case



Colour sensor integrated

Finalised test assembly

Targeted market case

LASSIE-FP7 USPs

- High color rendering
  - ≥ 90
- High color accuracy
  - 3 to 1 Step MacAdam on the Planckian-locus
- Constant color over time
  - Intelligence: sensor feedback loop

Niche target market

- High quality and high demanding
- Lighting in stores & boutiques
- Use case: “Color-proof islands”

Thank you for your attention!

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Acknowledgements:

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