Intelligent efficient solid-state lighting

12.12.2016, Pantheon, Muttenz BL, Swiss

Sensors for intelligent light management

Fraunhofer IIS

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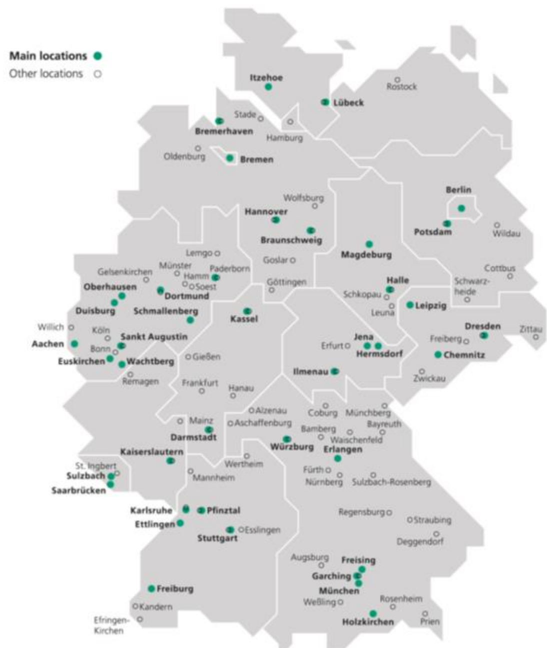
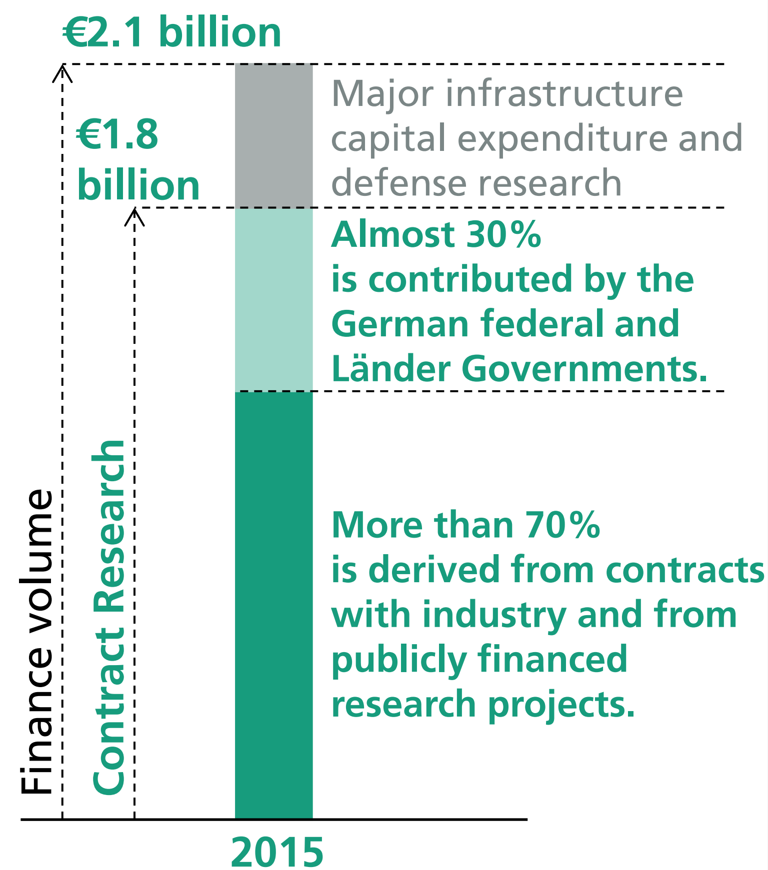
1. Introduction: Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society.

24,000 staff



67 institutes and research units



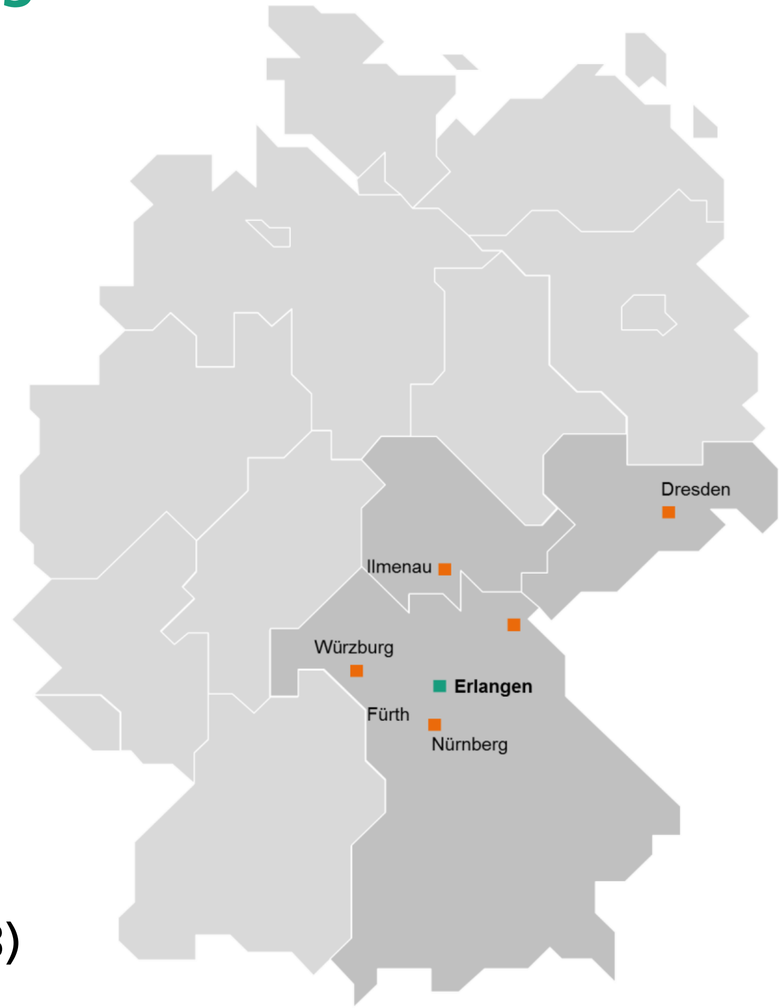
LASSIE-FP7

Fraunhofer IIS

1. Introduction: Fraunhofer IIS
Fraunhofer-Institute for Integrated Circuits IIS

- Founded in 1985
- More than 950 staff
- Budget approx. € 130 million
- Revenue sources
  > 75 % income from projects
  < 25 % public funding

- Range of Services
  - Feasibility studies
  - Contract research (R & D services)
  - Licensing of technologies (e. g. mp3)



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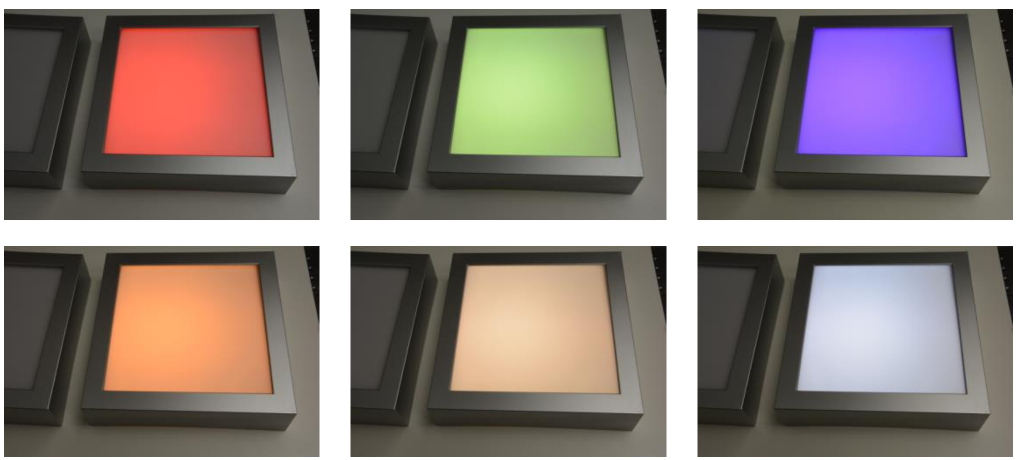
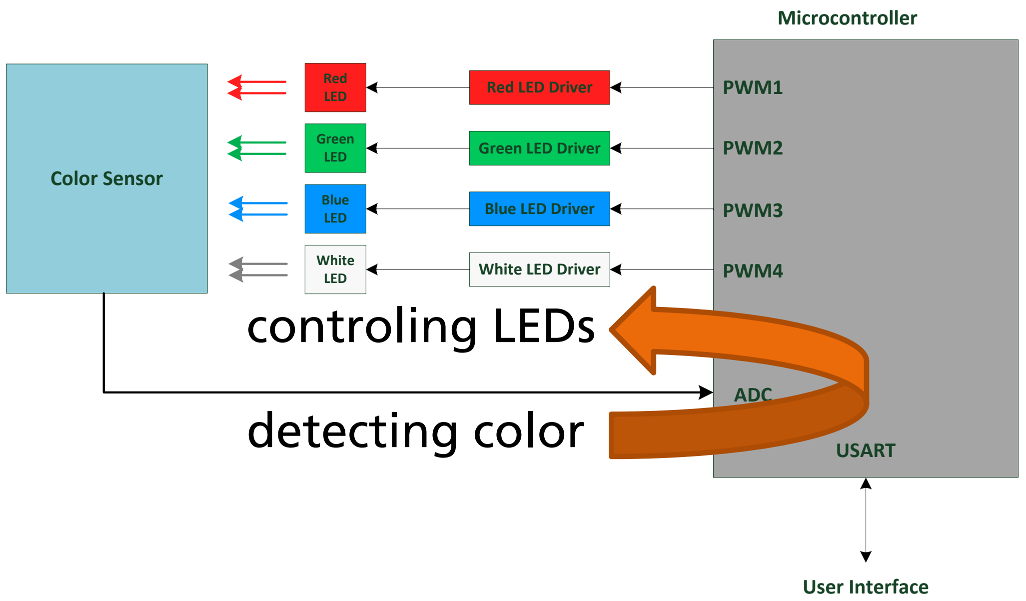
1. Introduction
Why color sensors for smart lighting?

- »Mixing« of light required for color tuning (»tuneable white«)
- High-quality lighting requires precise color matching over time and from luminaire to luminaire
- Wavelength of LEDs changes with temperature and due to aging
- ⇒ How to keep the color of a luminaire constant?



1. Introduction
Why color sensors for smart lighting?

- Color-sensing feedback is more reliable than binning and modeling temperature and aging effects of LEDs



- ⇒ Cost-effective color sensors are needed for high-volume illumination applications

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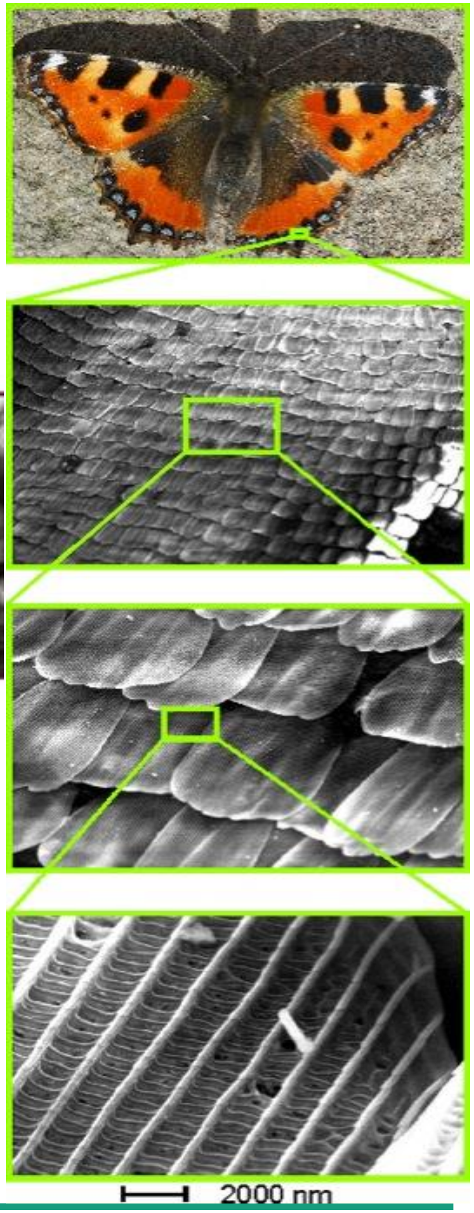
1. Introduction
Technologies for color sensors

- Various filter technologies are well established:
  - Absorption filters, e. g. red, green, blue pigmentfilters (Bayer filter)
  - Dielectric filters (thin film filters, interference filters)
  - In spectrometers: prisms, gratings, tunable filters

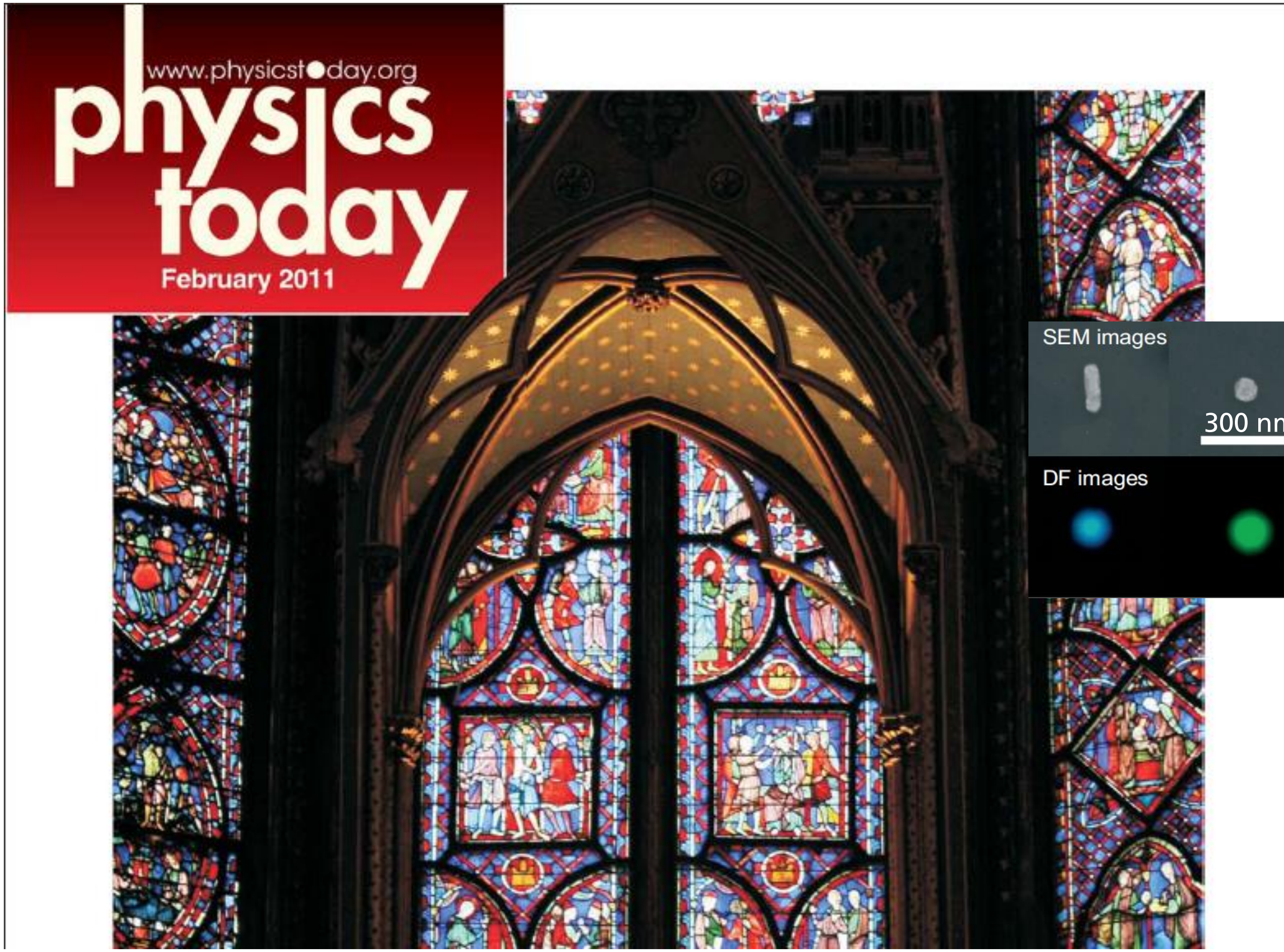
- Are there other approaches …
  - … feasible using CMOS semiconductor technolgy?
  - … enabling highly integrated sensors at low cost?

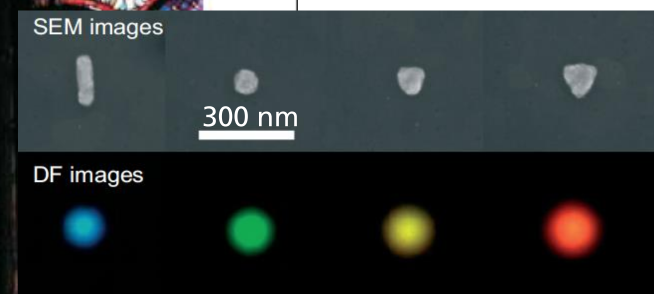
2. Methodology
Nanostructures in nature



2. Methodology

Nanostructures in art and science





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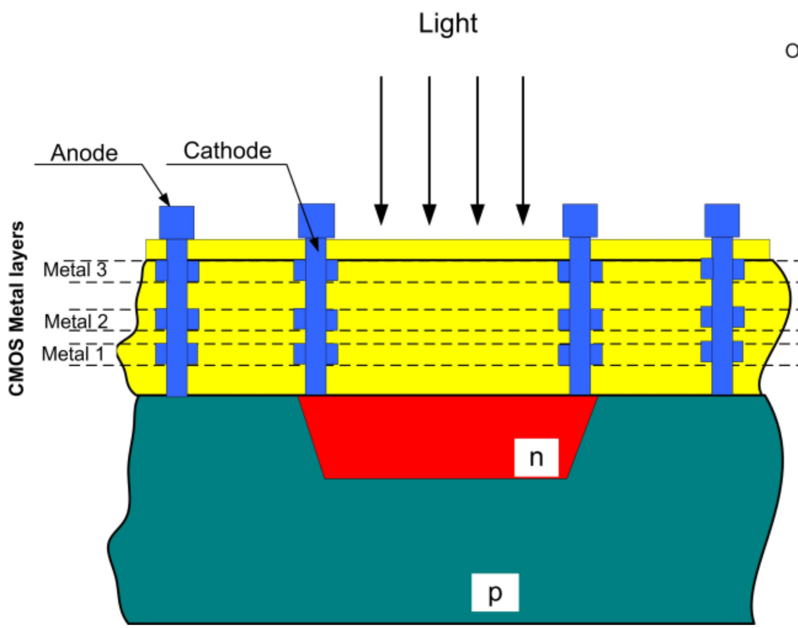
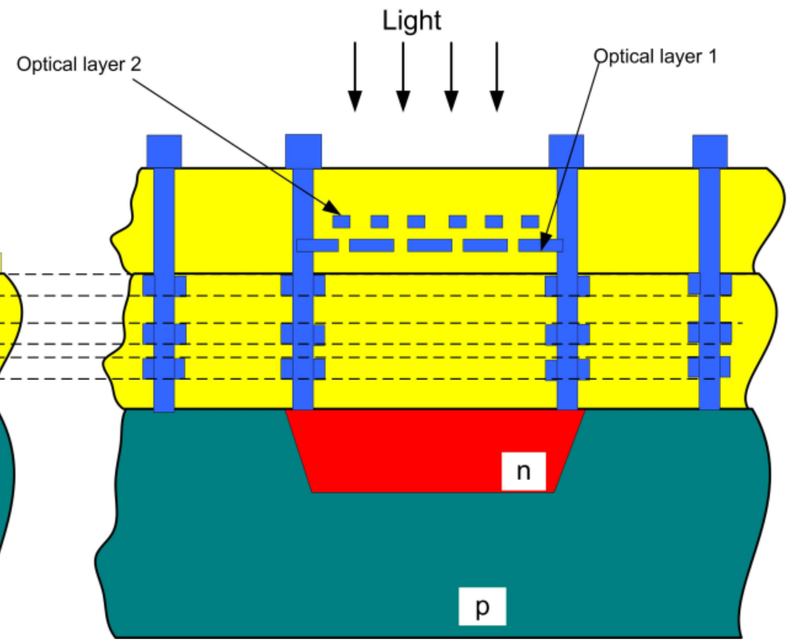
2. Methodology
Nanostructures as spectral filters

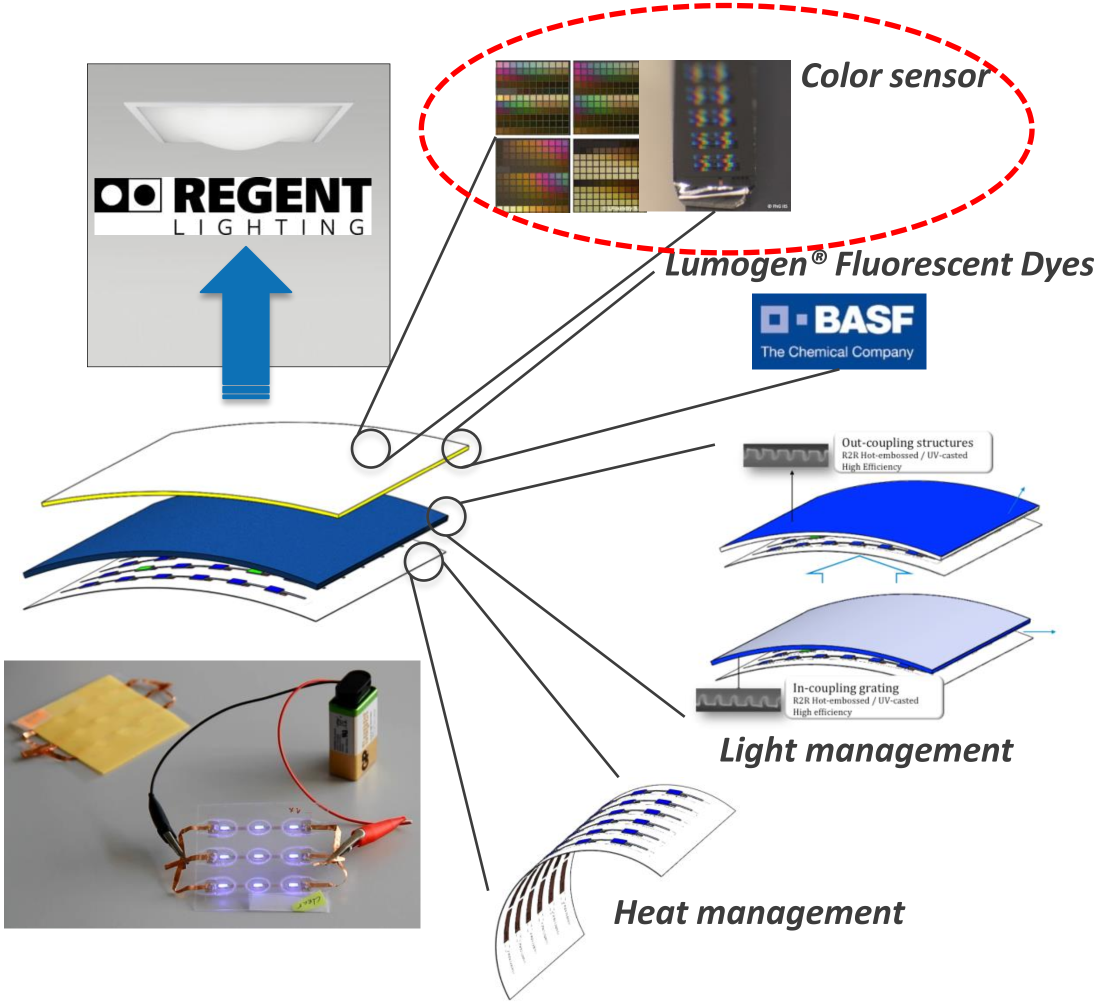


Conventional CMOS photodiode



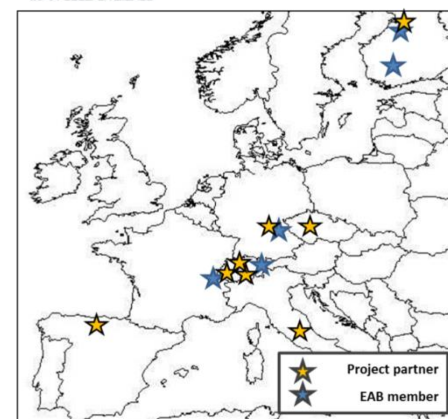
Photodiode with added metal layers as on-chip optical filters

3. EU-funded project »LASSIE-FP7«
Large Area Solid State Intelligent Efficient luminaires



SEVENTH FRAMEWORK PROGRAMME

csem · BASF The Chemical Company · VTT · REGENT LIGHTING · Fraunhofer IIS · Fraunhofer IISB · LFoundry · GAIKER ik4 research alliance · AMIRES



Property of the LASSIE-FP7 Consortium

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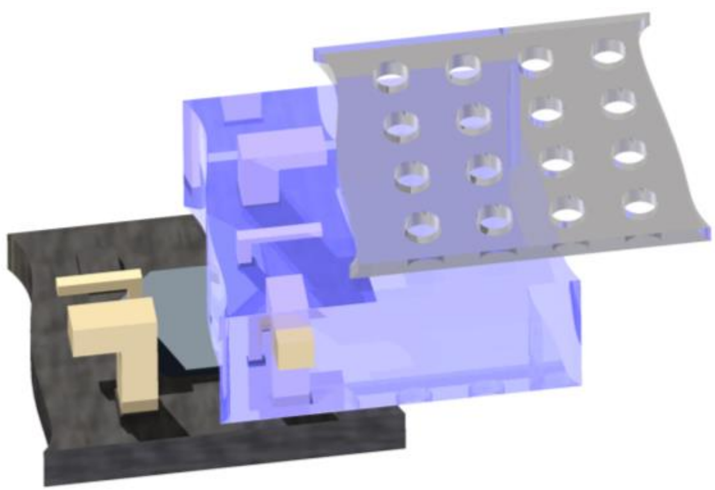
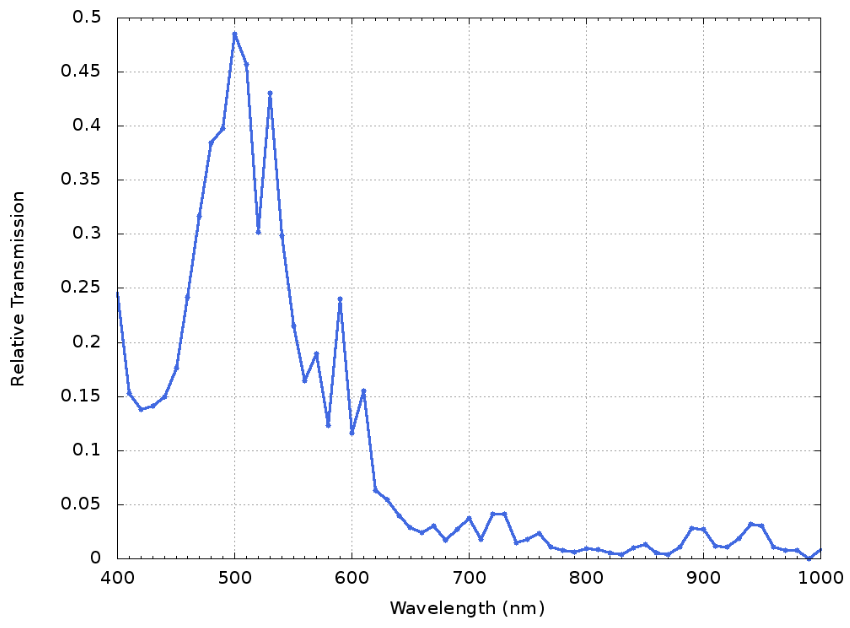
3. »LASSIE-FP7«

CMOS nanostructures as color filter

- Hole arrays with a typical period of 200 – 400 nm and »enhanced transmission« due to plasmon resonances are used
- Filter wavelength is tailored by varying the geometry

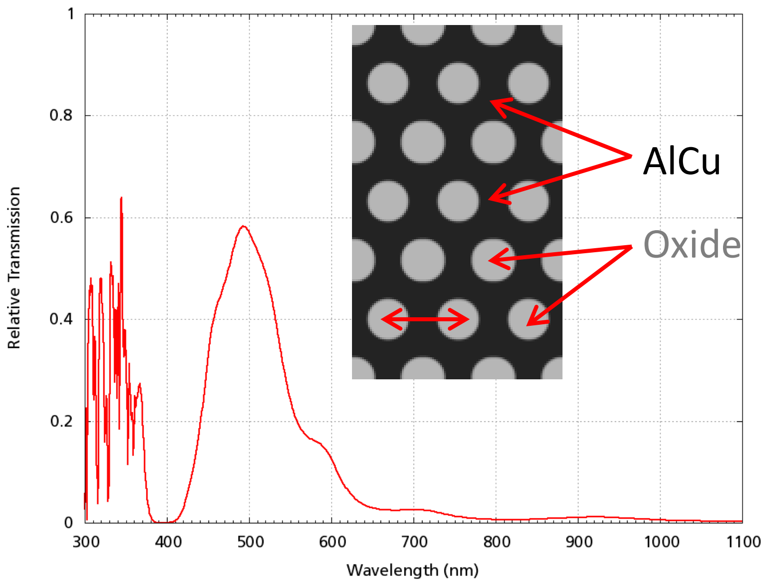




3. »LASSIE-FP7«

Simulation of metallic nanostructures

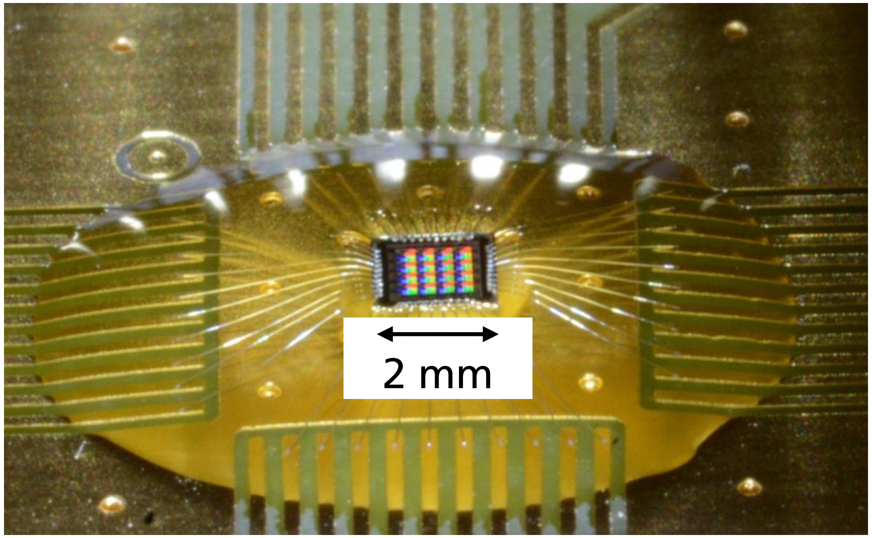
Simulation: green filter (band pass)

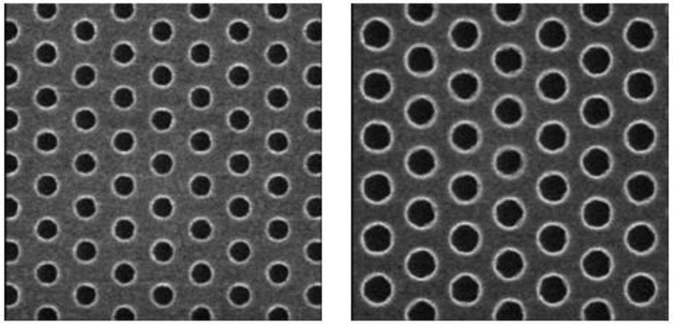


Spectral transmission of a hole array
(period 280 nm)

3. »LASSIE-FP7«
Fabrication of CMOS color sensors

LFOUNDRY
A SMIC COMPANY

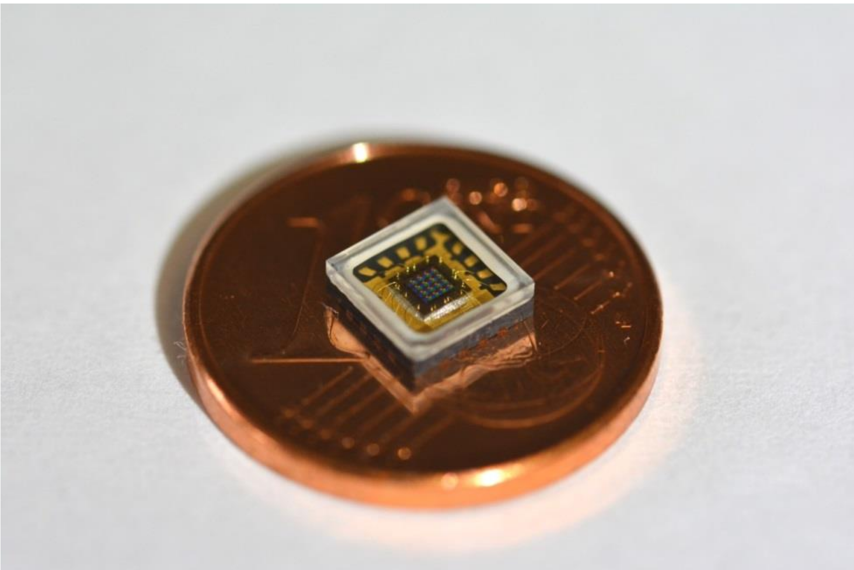




Sub-wavelength hole arrays
act as plasmonic filters

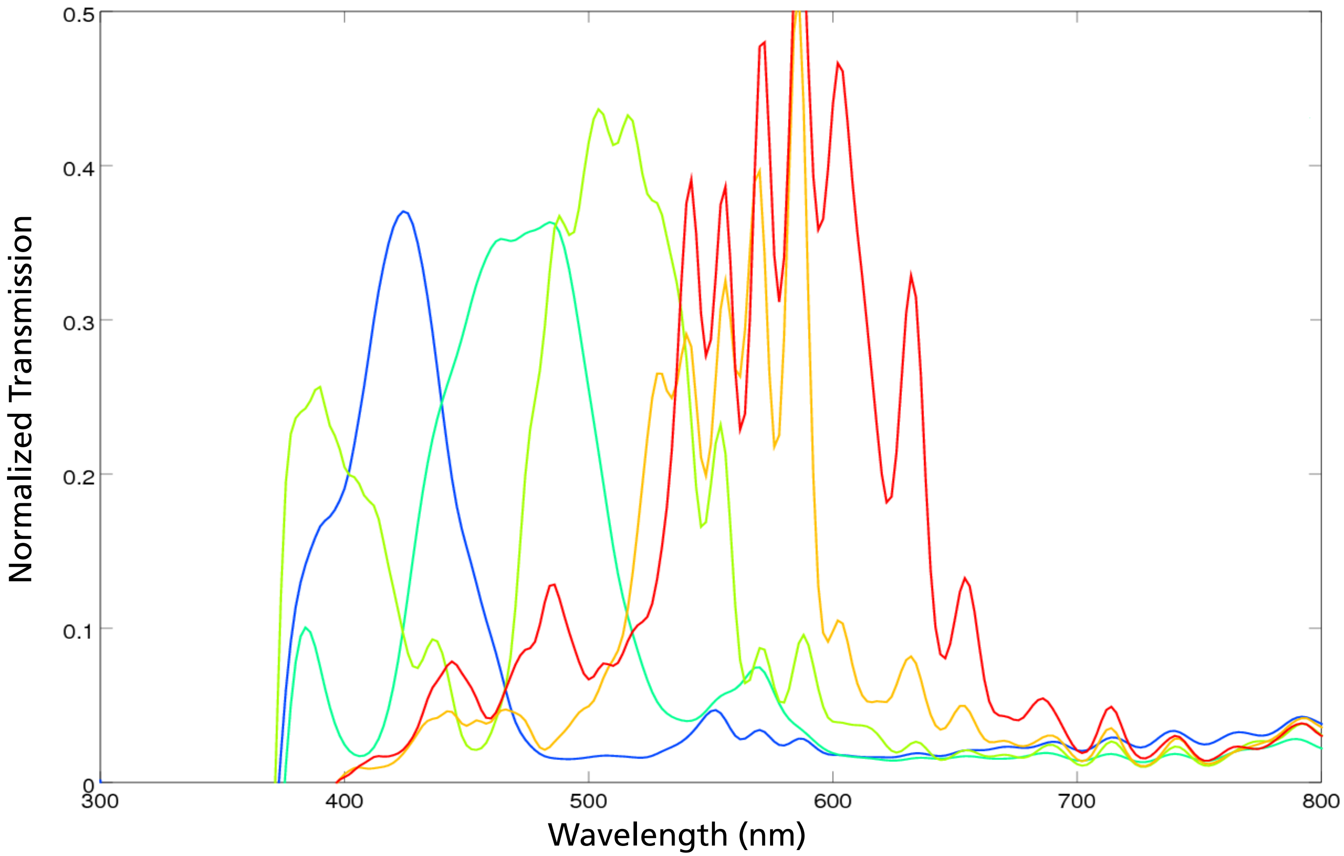
Sensor chip wire bonded on test board

3. »LASSIE-FP7«
Packaged CMOS multispectral sensor



- Photodiode array
- 12 spectral channels (400-700 nm)
- Amplifiers integrated on-chip
- Switchable gain, high dynamic range
- Configuration and data acquisition using microcontroller
- Small package (5x 5 mm^2)
- Low cost at high volume

3. »LASSIE-FP7«
Spectral response of sensor channels (selection)



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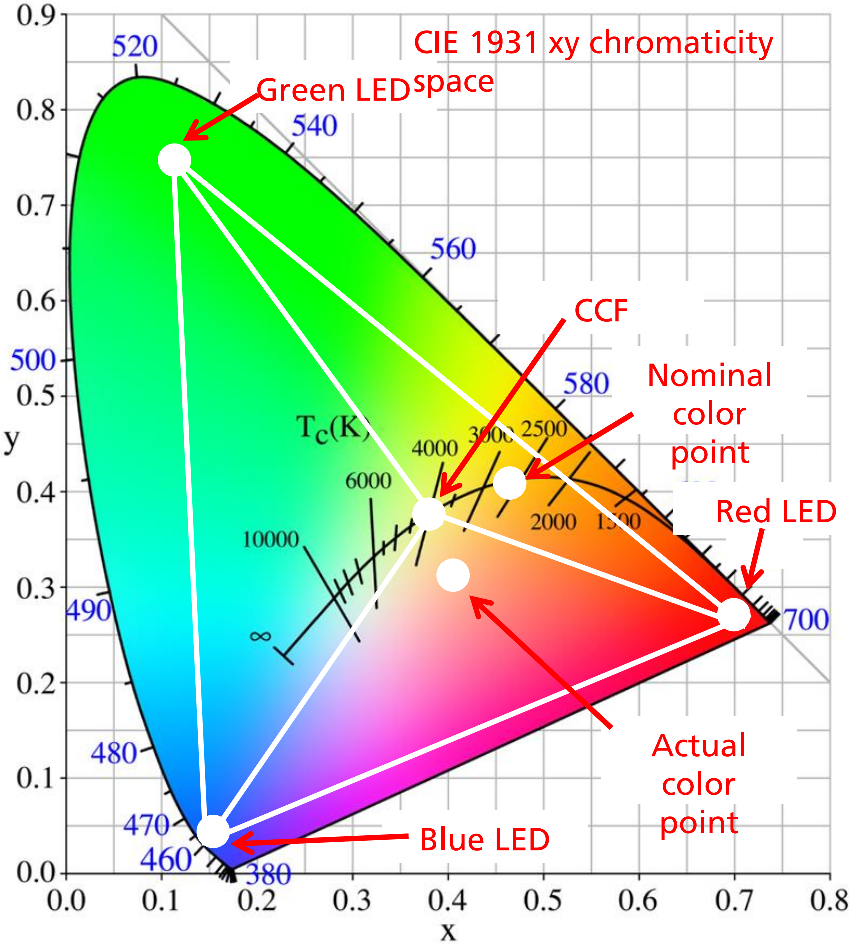
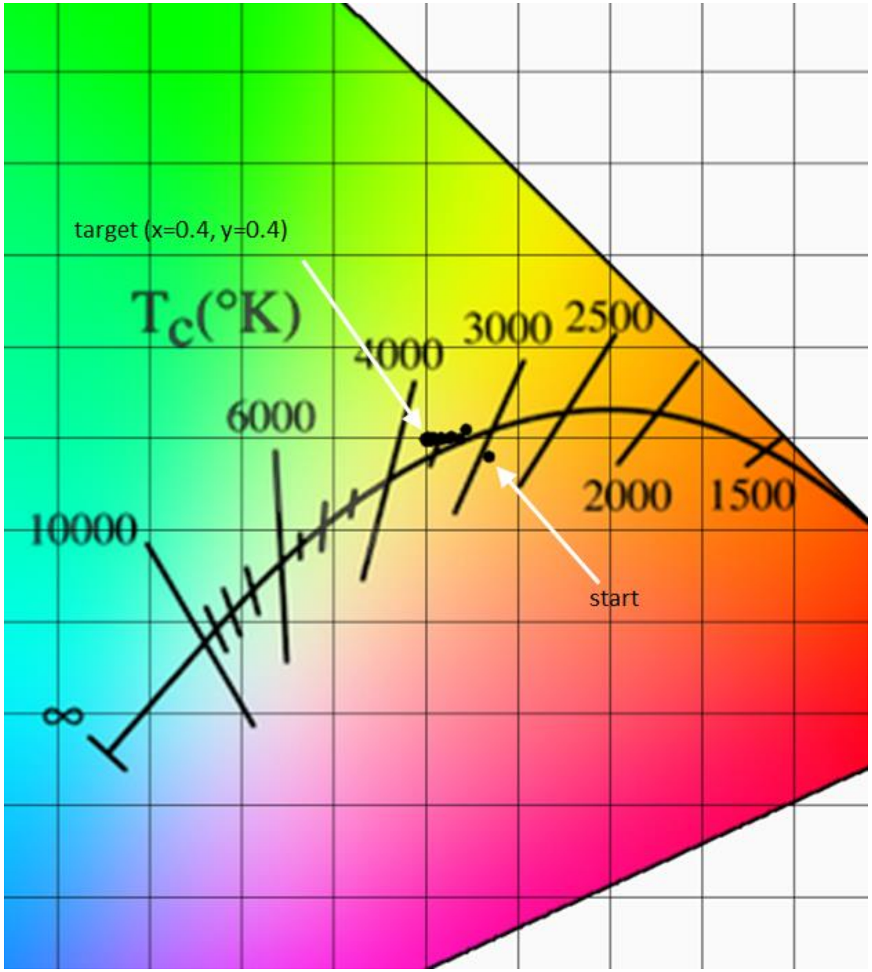
3. »LASSIE-FP7«

Color tuning example



- Colour conversion film for 4000 K
- Red + green + blue LED for colour tuning
- Achievable tuning range depends on color conversion film and LEDs chosen

3. »LASSIE-FP7«
Color feedback loop



- Feedback control algorithm tunes from actual to nominal colour point iteratively
- Color (chromaticity coordinate) is kept constant at target value
- Temperature and aging effects of color conversion film and LEDs are compensated over the lifetime of the luminaire

4. Multispectral sensors
Other applications

- Multispectral ambient light sensor for smart lighting
  - more spectral information than intensity or RGB sensors
  - detection of ambient light, adjusting LED lighting
- Color sensors for high temperature or humidity conditions, e. g. for automotive and industrial applications
- Miniaturized multispectral sensors for analytics of gases and fluids, e. g. point-of-care applications
- Application specific multispectral sensors with tailored spectral filters and signal processing on-chip

5. Conclusions

- High-quality LED lighting systems benefit from color feedback sensors
- Photodiodes with on-chip color and multispectral filters can be fabricated in high volume at low cost using a CMOS process
- Implementation of color feedback loop in order to stabilize the chromaticity point of LED luminaires demonstrated in »LASSIE-FP7«