ILLUMINATING THE DESIGN PROCESS

Human Factors at the heart of LED-based interior lighting design:

a new design methodology

OPTIS SAS
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www.optis-world.com

Content:

- LEDs advantages compared to incandescent light sources
- Simultaneous management of thermal and optical parameters due to CAD integration
- Human Vision effects, their simulation and representation in virtual environments
- Effect of LED light on human factors
- Optimization of car interiors for driver and passenger visual comfort

LEDs advantages compared to incandescent light sources

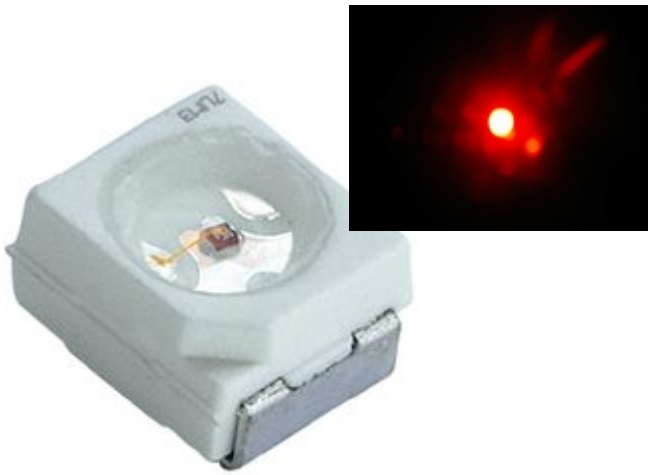
Green lighting (Higher Efficiency, less CO_2)

LED for general lighting

	15th	19th	20th century...		
				 HID	 LED
Efficiency lm/W	1	10–15	70–100	70–100	Target* 50-110
Efficiency (rel.)	<1%	5–9%	25–30%	30-35%	Target 20–30%

* Depending on LED color/type and driving conditions

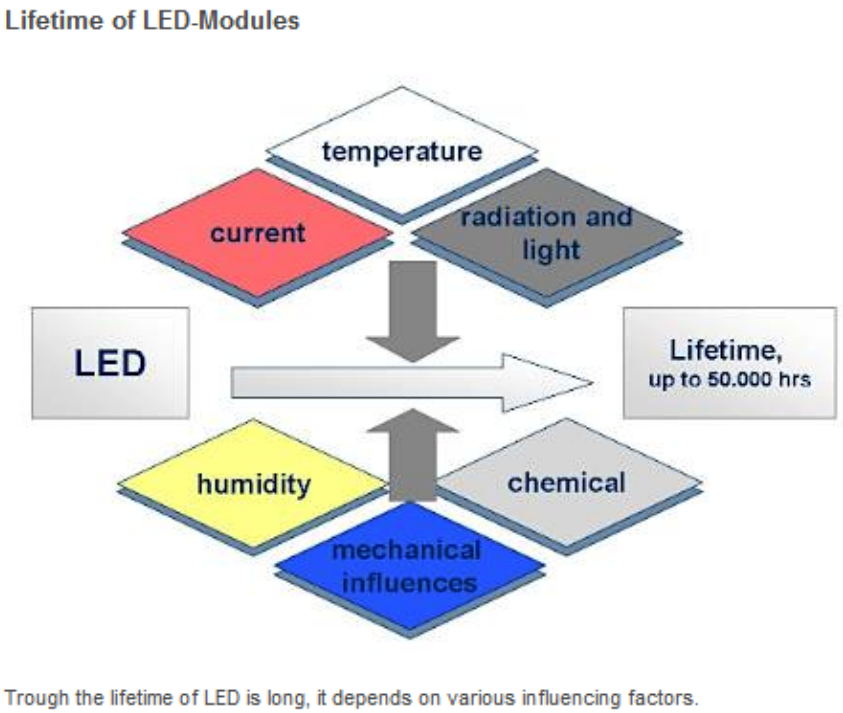
Data extracted from www.osram-os.com



RED topled with 62 lm/Watt efficiency

As we can see LEDs have a much higher efficiency compared to incandescent lighting and as such the emission of CO2 gases can be drastically improved by using LEDs. In the future the efficiency of LEDs will reach the level of HID lighting and such, replacing more and more standard light bulbs in interior and exterior applications.

Longer Life Time (reduced maintenance cost)

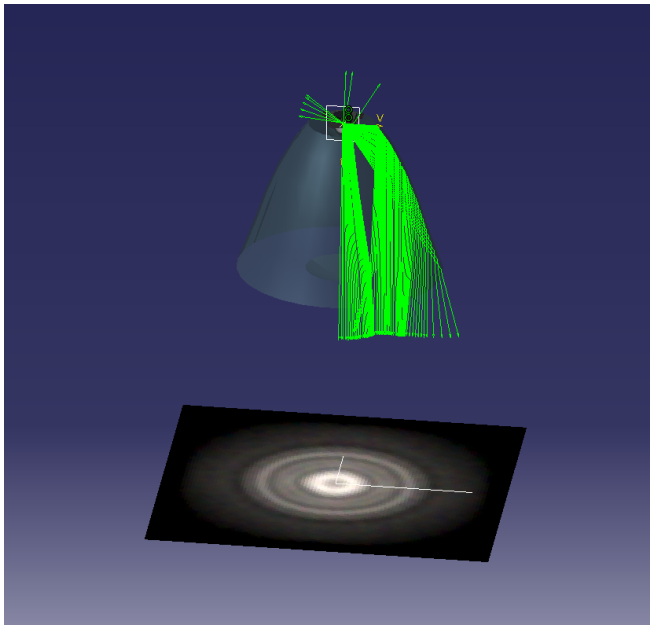


Data extracted from www.osram-os.com

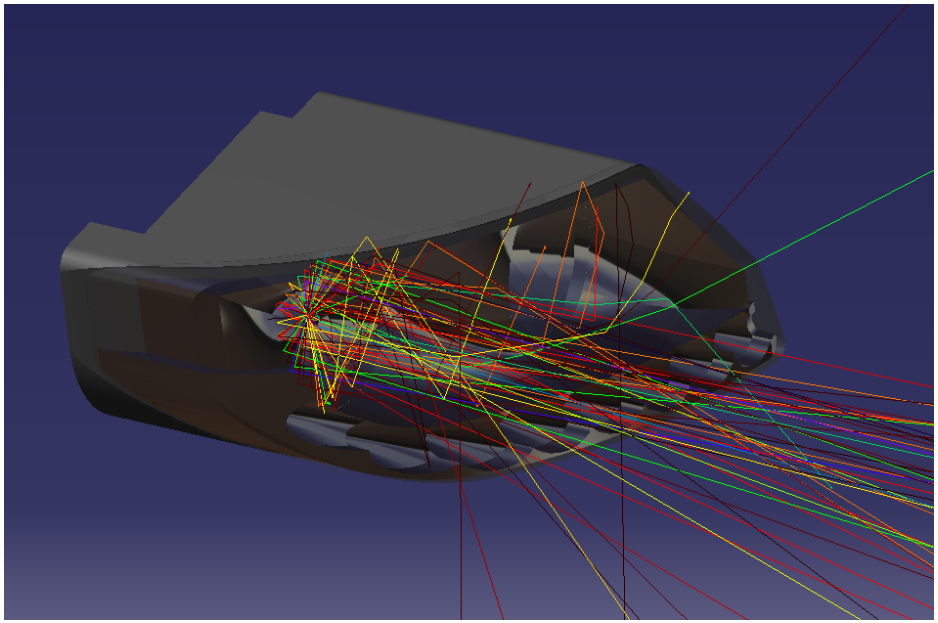
Geobulb: A LED Light Bulb Replacement

LEDs have a much longer lifetime of 50,000 hrs to 100,000 hrs depending on different factors. Incandescent bulbs have lifetimes of about 1000 hrs, depending on environment factors like vibrations. If you consider the lifetime of a car for 10 years we need to reach 86400 hours, meaning that LED lights do not need to be changed if reasonably used.

Size of the light source and lamp



An LED is an directive light source which can have integrated optics; If additional optics is needed it just can be added to the front, no need for a reflector.

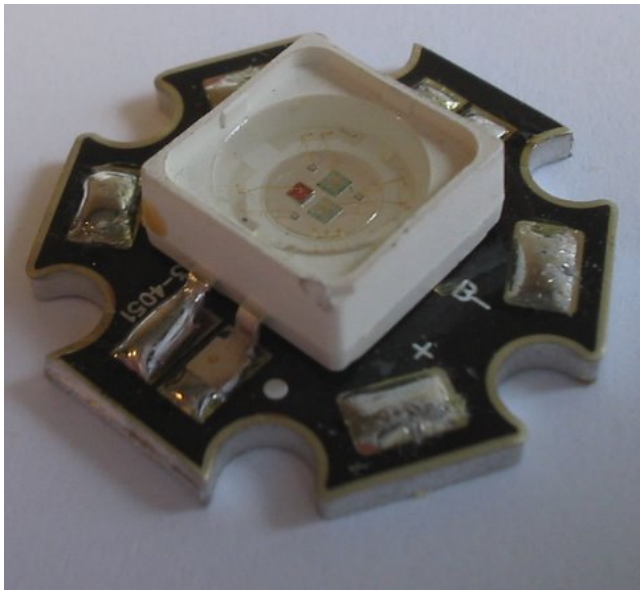


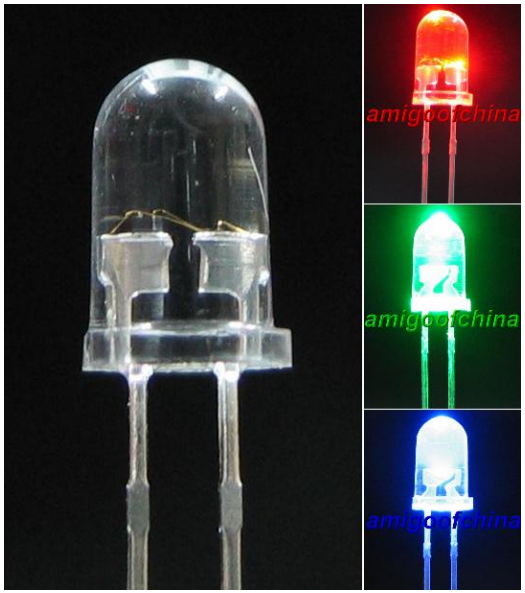
An incandescent bulb is an isotropic source emitting in all directions; which needs reflector and lens elements to shape the light emission

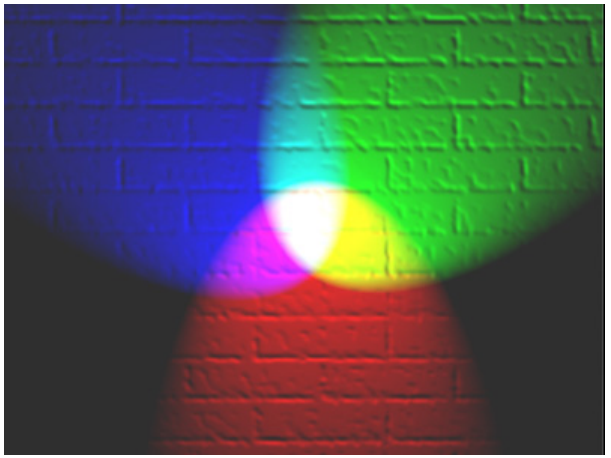
Switchable and Dimmable

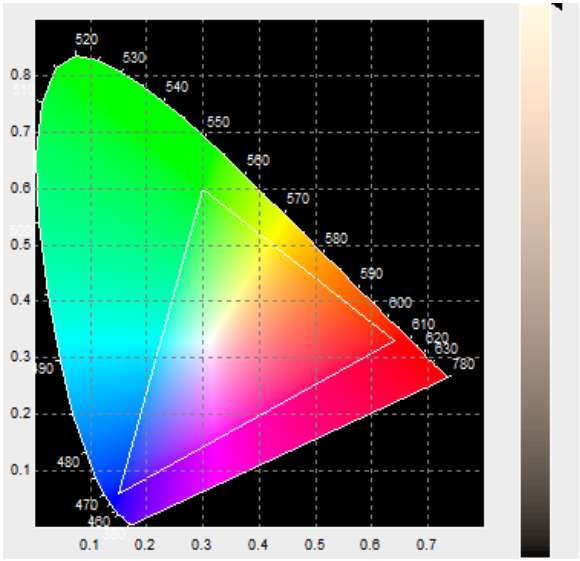
LED Light is switchable and dimmable without reducing lifetime. This makes it possible to create moving elements like this waterfall light on a mobile phone

Color on demand









Using LEDs with multiple chip emission it is possible to mix these colors with others, changing the driving current for each chip. Using the correct basic colors and additive color mixing it is possible to achieve white and any other tone within the color gamut.

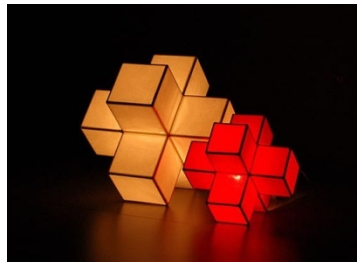
Enhanced Design features (dot, line, surface)

1D Spot

1D Line

2D Panel

3D Cube

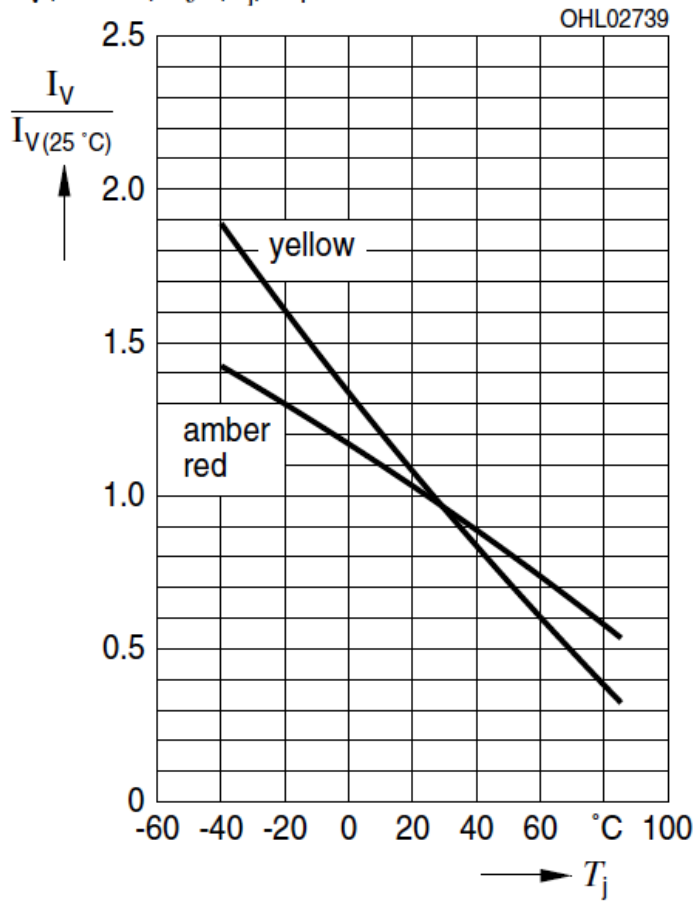


The use of LED lights gives a maximum of design freedom for interior lighting as all possible light emission geometries are available and easy to control for brightness and color.

Simultaneous management of thermal and optical parameters due to CAD integration

Influence of ambient temperature on LED Power

Relativer Lichtstrom[2] *Seite 18*
Relative Luminous Flux[2] *page 18*
$I_V/I_V(25\ °C) = f(T_j);\ I_F = 140\ mA$



Example: OSRAM LA G6SP and LY G6SP

As you can see the LED Emission is dependant on the Junction Temperature, which is the temperature of the Junction between p and n material where the light is generated.
Nominal data is given in the datasheets for a junction temperature of 25 degrees, so the same as the ambient temperature.
If driving current through the LED, the chip will heat up. You can see that the red LED will lose about 50 percent of the initial flux when heated to 60 degrees.
The degradation is strongly dependent on the chip material and as such on the emission color.

Influence of ambient temperature on LED Power

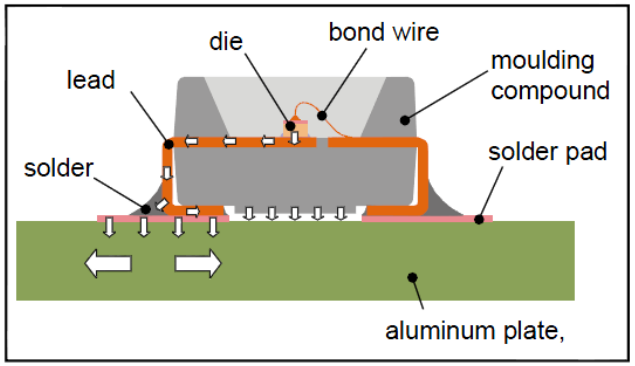


Figure 1: Internal Structure of SMT LED Package

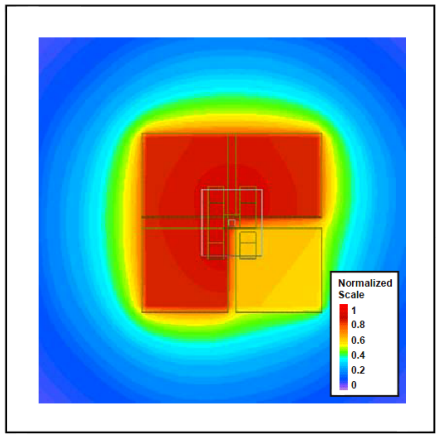


Figure 9: Substrate material with thermal conductivity of 0.2 W/(K m) (in the range of FR2)

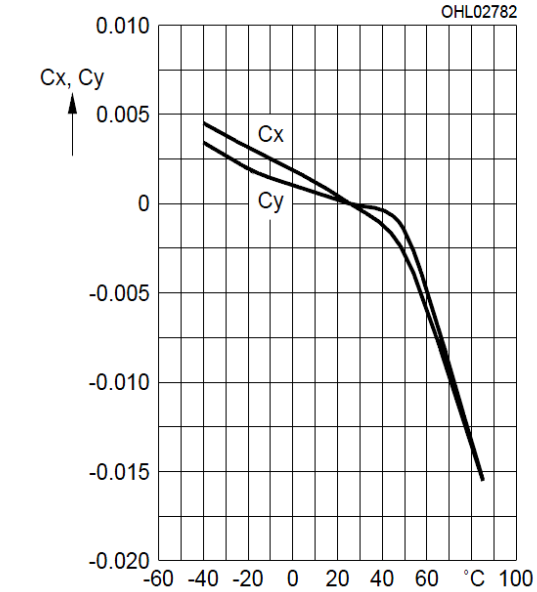
So in order to have a constant LED emission it is necessary to dissipate the heat from the die over the leads to the PCB.
Using different types of PCB (single layer, double layer) this heat dissipation will be more or less effective.

In order to know the light output of the LED it is necessary to execute a thermal simulation taking into account ambient temperature, PCB, active or passive cooling devices.

Influence of ambient temperature on LED color

Example: OSRAM LW G6SP using yellow phosphor

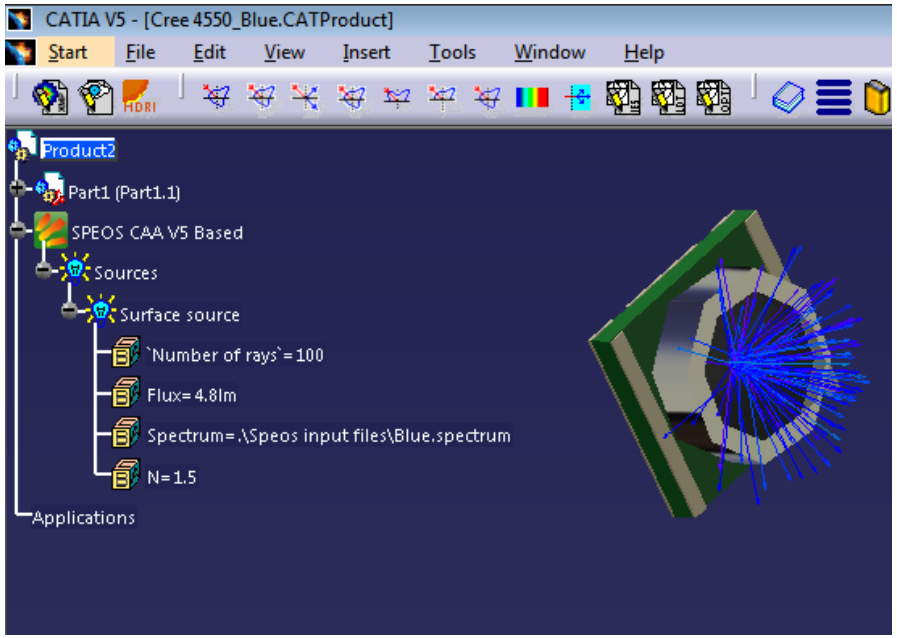
Farbortverschiebung[2] *Seite 18*
Chromaticity Coordinate Shift[2] *page 18*
x, y = $f(T_j)$; I_F = 140 mA

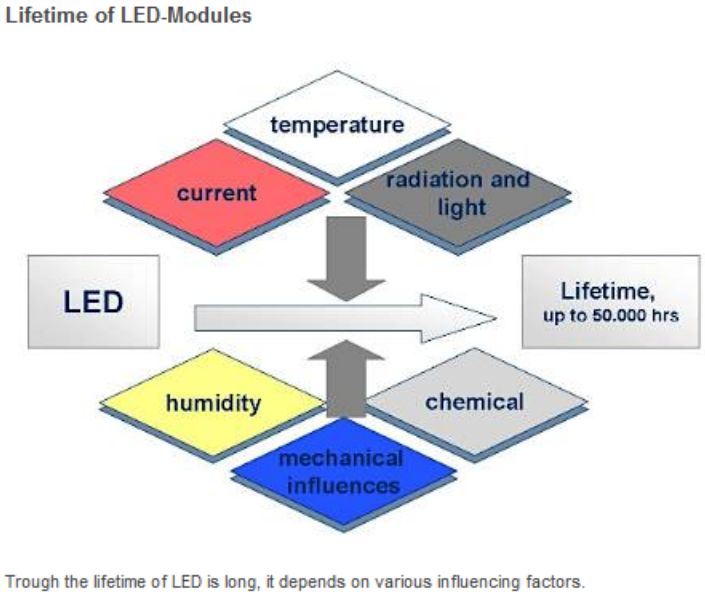


As we have seen the dependency of optical flux emission and temperature depends on the chip material, so the emission color.
Like this it is evident that using RGB LEDs, a temperature change will result in a color change.

But also in the case of white LEDs using a phosphor material to transfer blue to white light the emission color will depend on the wavelength as the optical power of the blue chip will depend on the temperature.

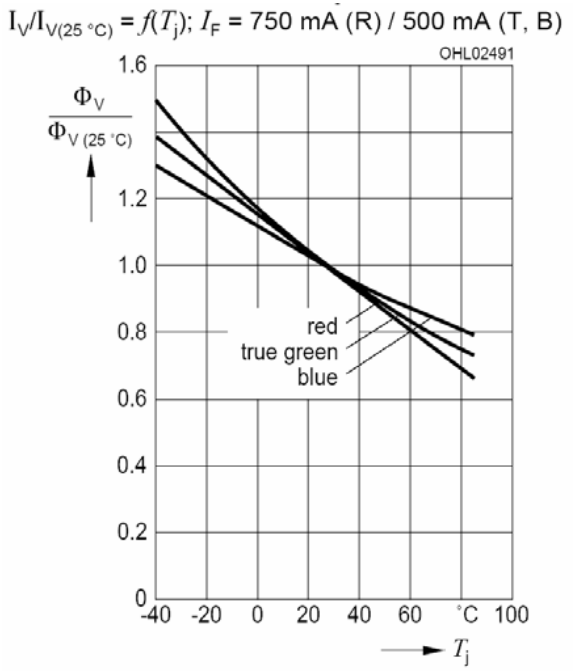
CAD Integration advantages





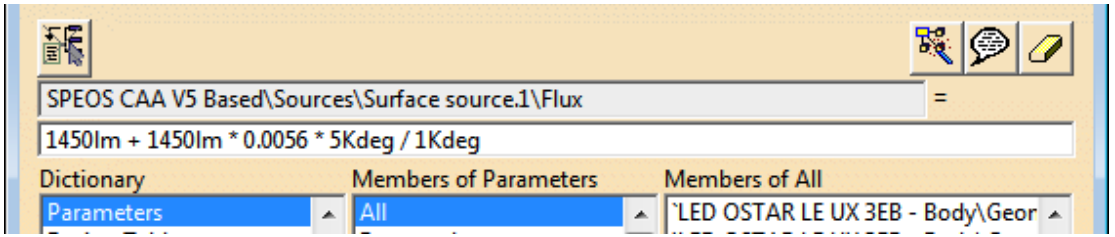
Using a software which is 100 percent integrated into CAD as a workbench, add-in or other nomination, so not using a “bridge” connection, has the advantage that the mechanical and thermal conditions will be translated into CAD parameters.
Also the optical emission parameters are available as CAD parameters. So it is possible to create a loop between a thermal simulation upfront and the optical emission using a LED coming from OPTIS source library. The CAD user does not need to leave his working environment between the single simulation tasks and it is possible to optimize all environment parameters in one single step.

Application Example 1

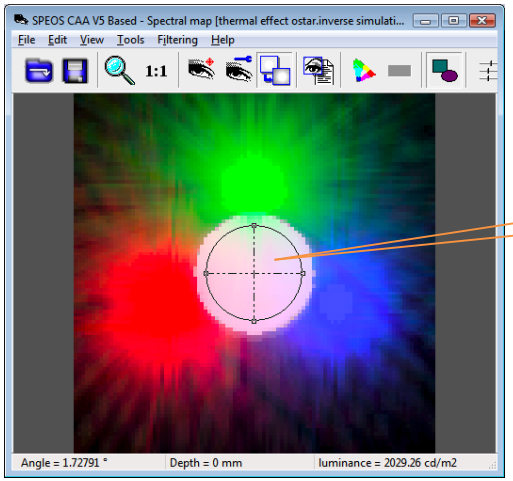


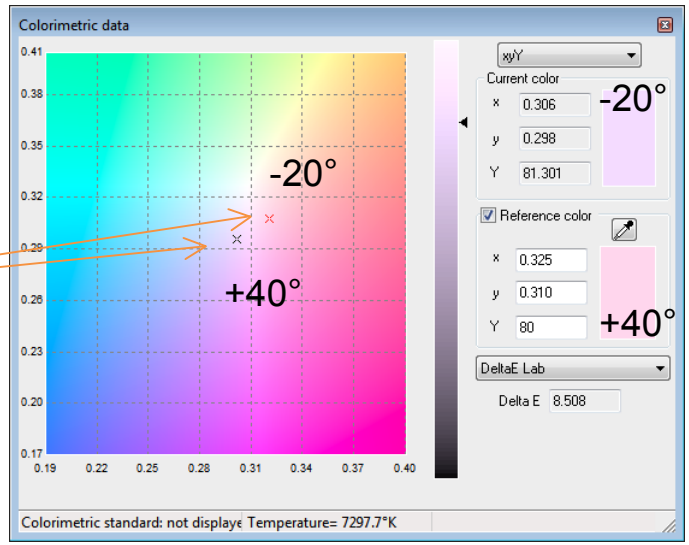
Relative Luminous Flux vs Junction Temperature (e.g. OSTAR® Projection LE RTB-A2A)

The emission Power will be dependent on the ambient temperature; this effect is taken into account in the simulations for example by using CATIA V5 formulae:

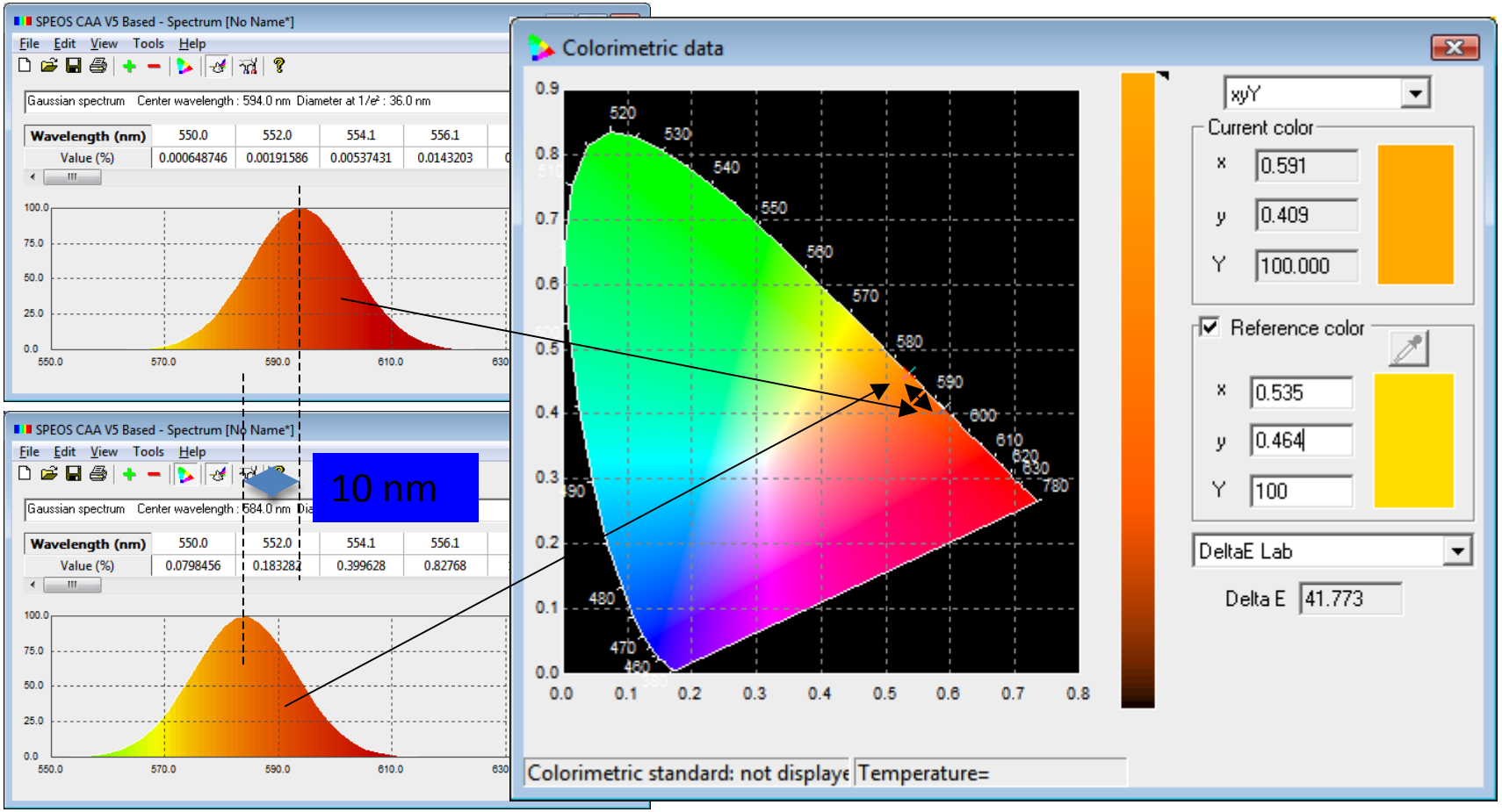


If we mix three LED colors, we can translate the power shift to a shift of chromaticity coordinates:





Application Example 2



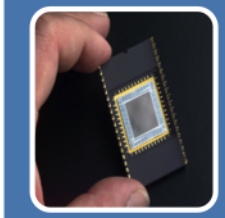
Influence of a 10 nm shift on a Gaussian spectrum emission near to a yellow LED – The shift is clearly visible

Human Vision effects, their simulation and representation in virtual environments

Human Vision and Camera Vision

Sensor

- 120 MP
- 8 MP in high illumination

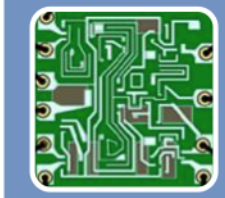


Sensor

- 5 to 10 MP

Processing

- 50 billions of neurons
- > Trillions of synapses



Processing

- 1 connection for each pixel

Result

- Colors
- 3D Images
- Emotion, Reaction

Result

- Colors
- 2D Images

Construction of Shape and Depth

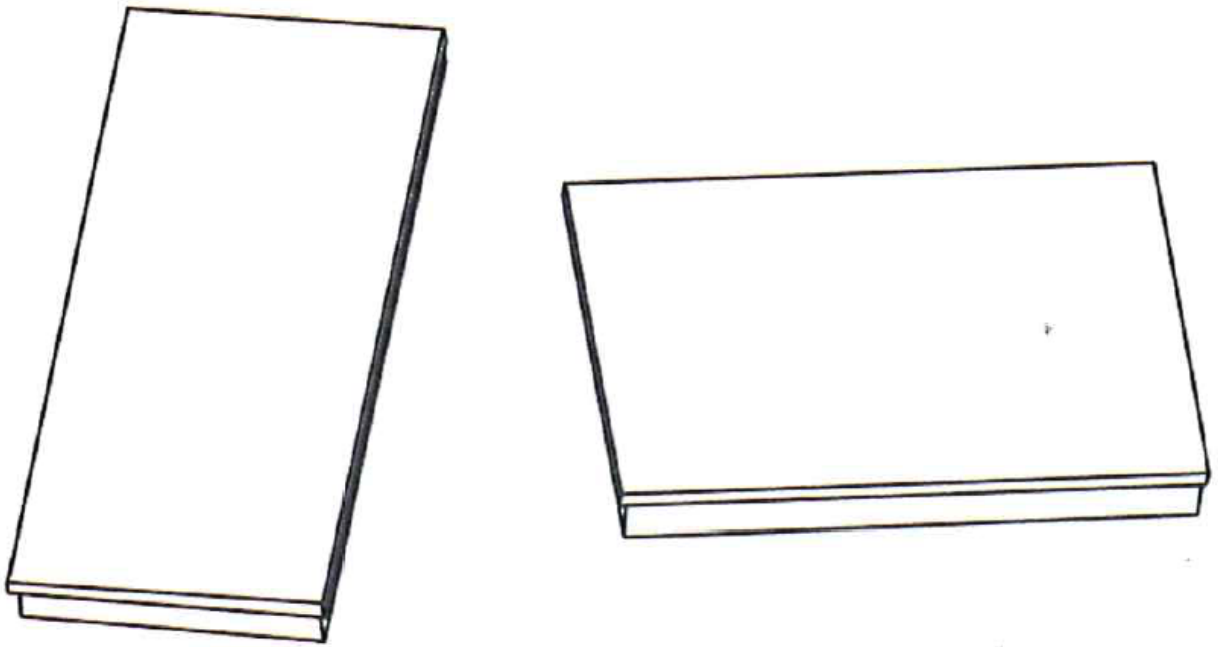


Fig. 2.1 Two boxes. The box on the left looks long and narrow; the box on the right looks short and fat. In fact they have the same dimensions. You can check this with a ruler.

Construction of Lines and Shades

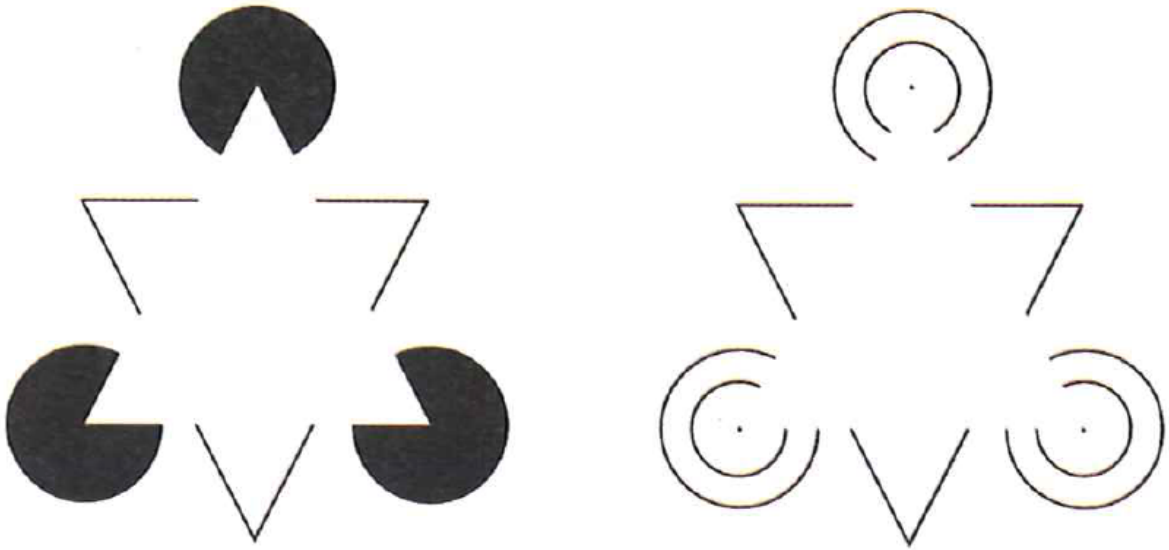
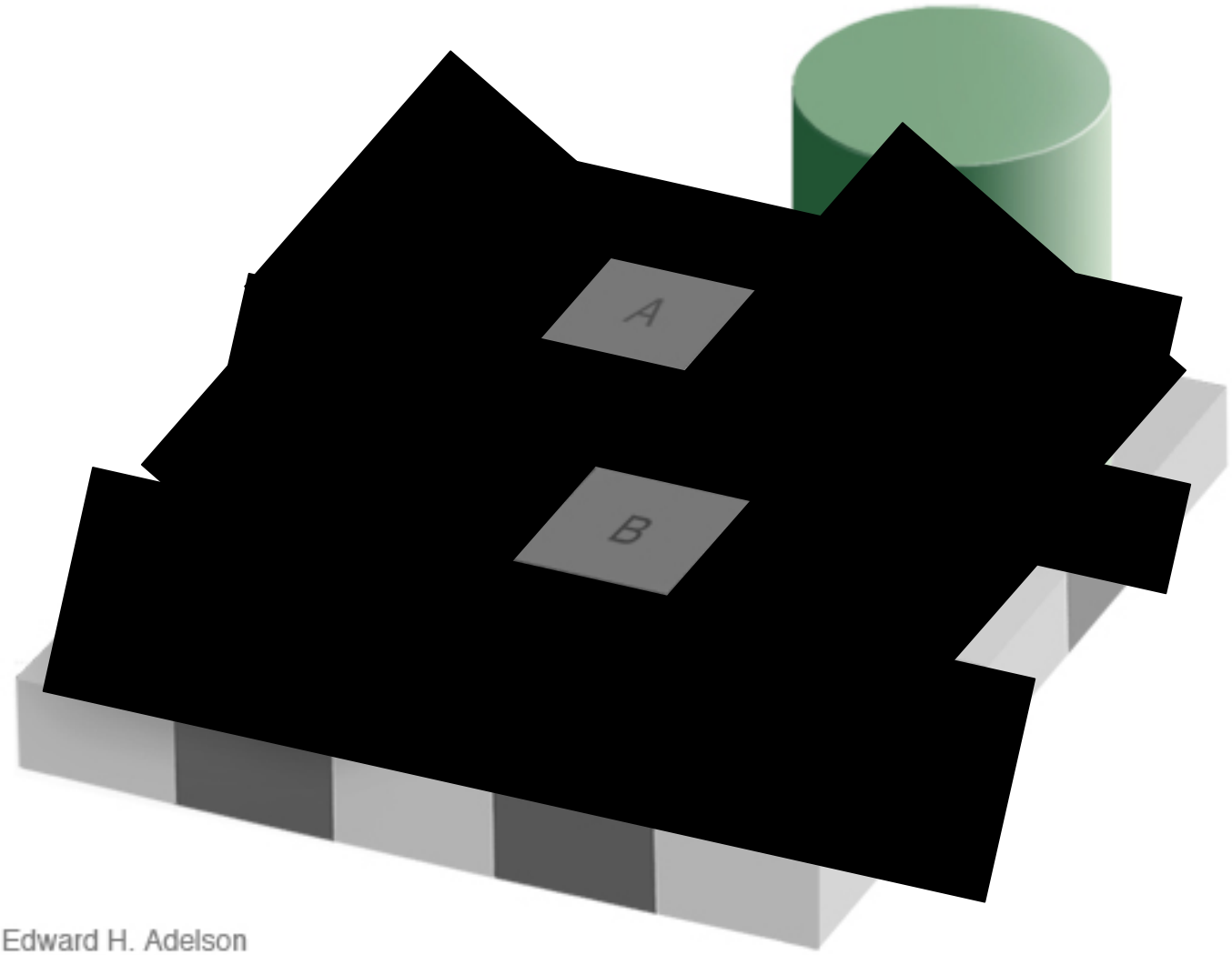


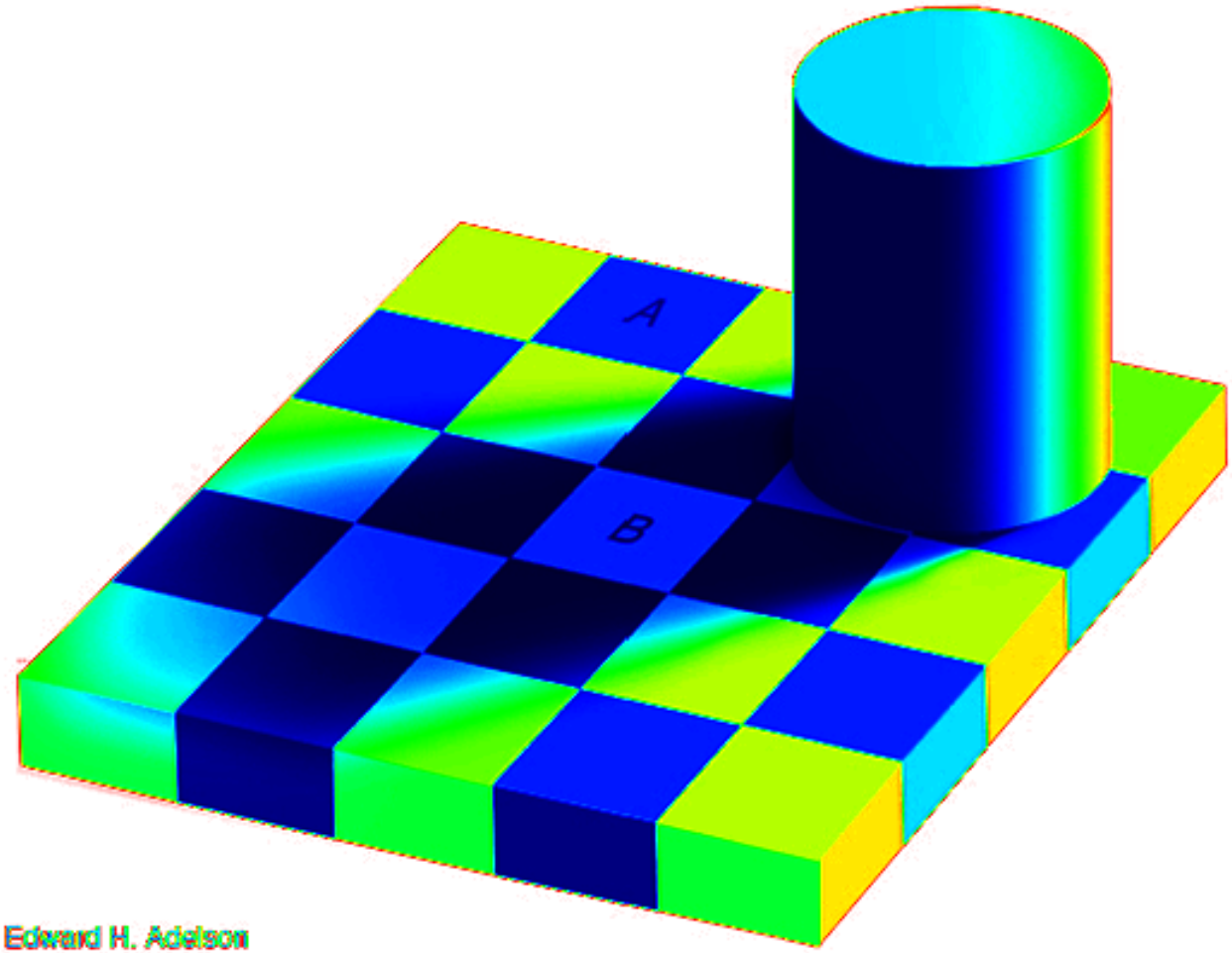
Fig. 2.4 Kanizsa's triangles. You see two white triangles with clear edges, and with interiors that appear to be a brighter white than the surroundings. In fact the triangles, including their edges and brighter interiors, are all illusory constructions of your visual system.

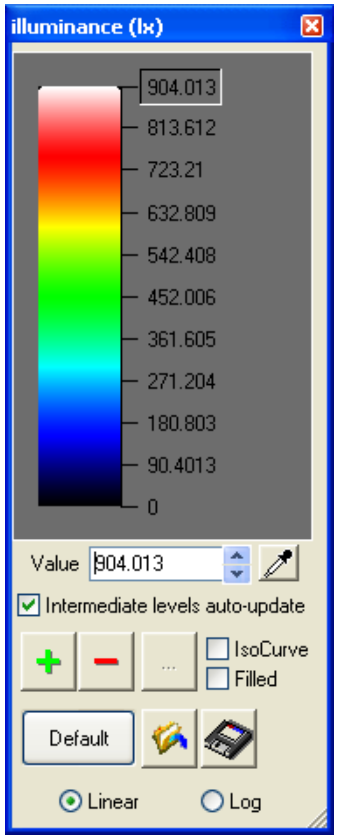
Vision Game



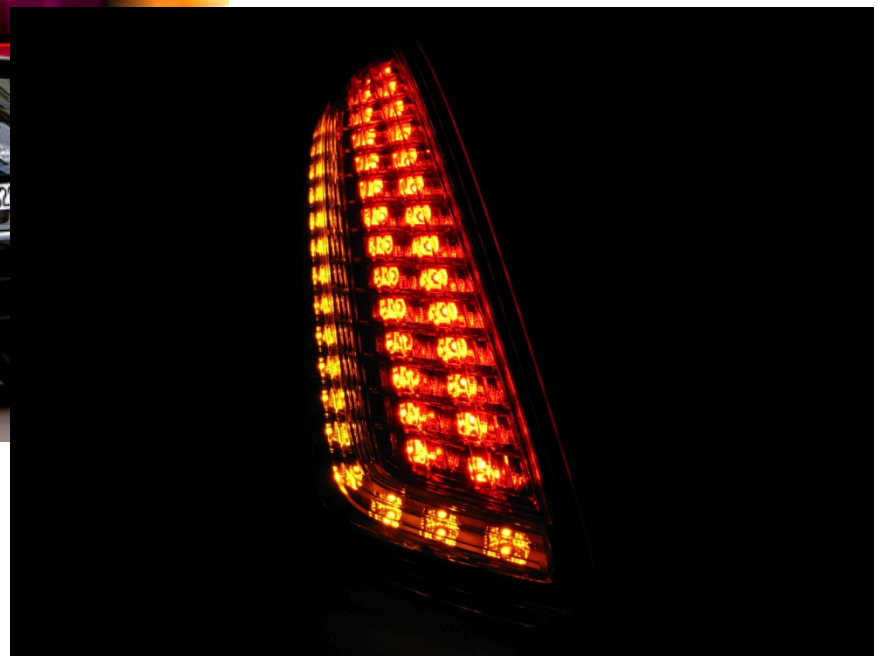
Edward H. Adelson

Solution – We need physics based simulation

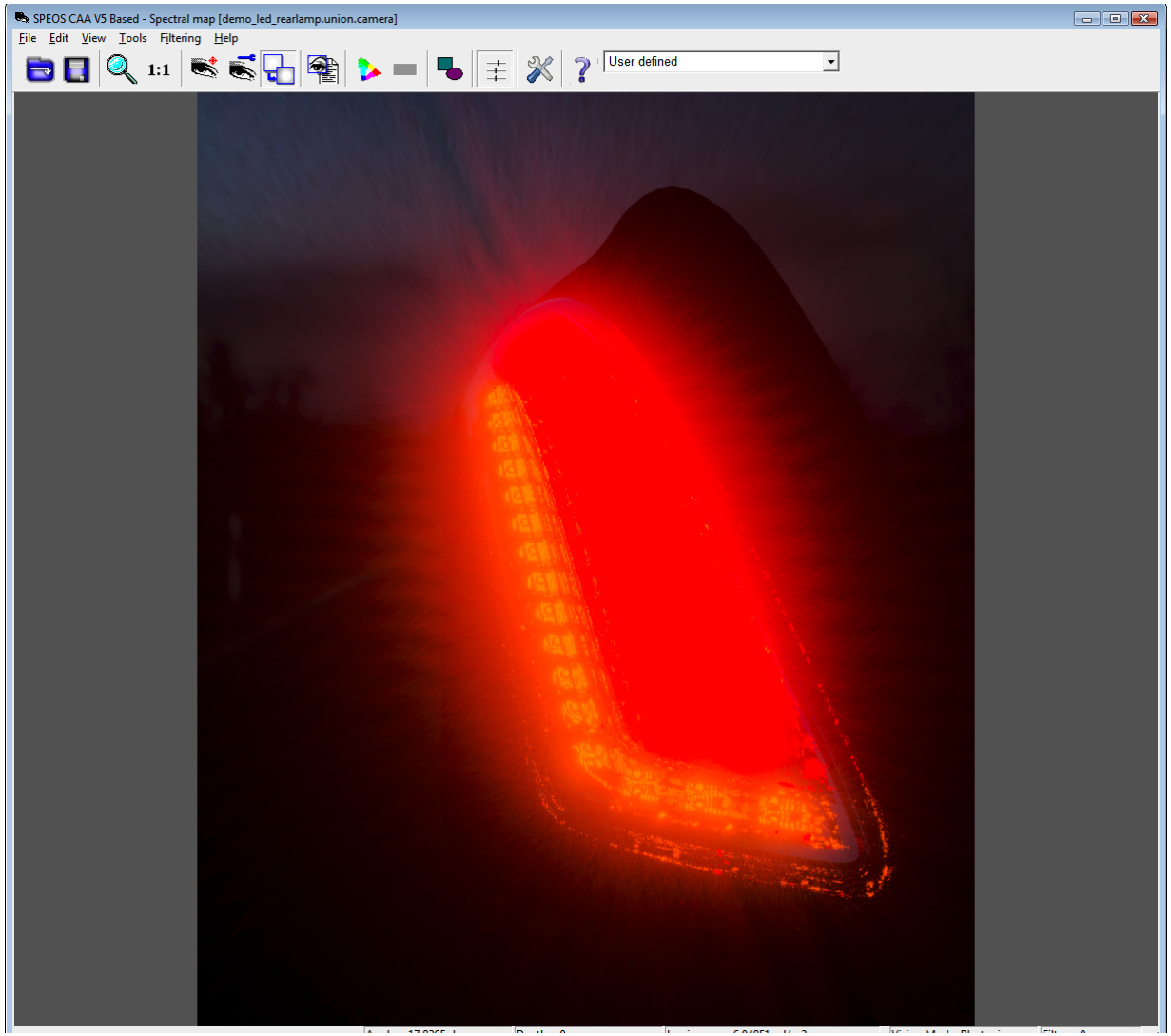




Representation Methods influence



Example: Lancia Delta Taillamp Study by OPTIS

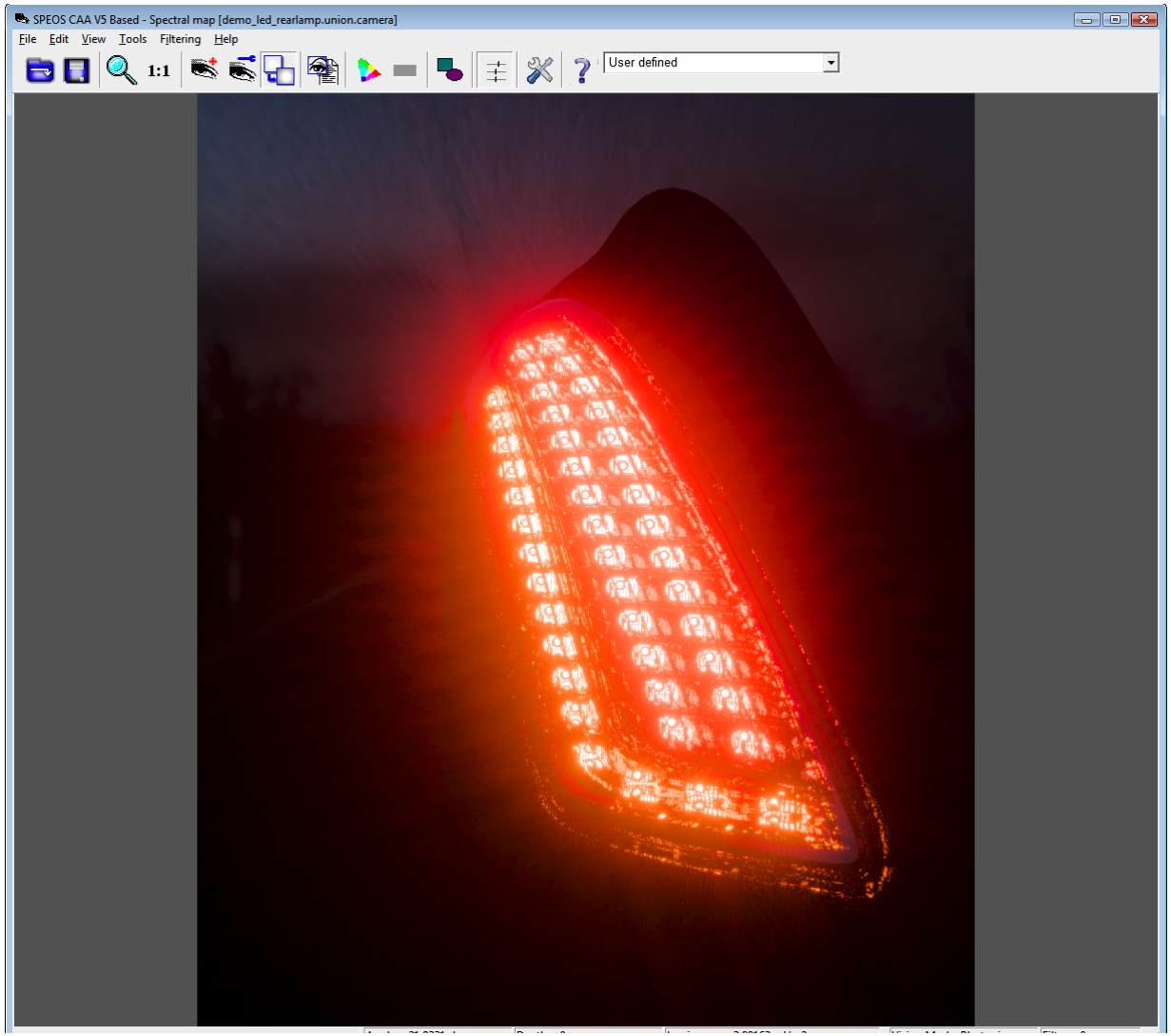


Glare Effect:
Vos, 1984

Display Mode:
Gamut Clipping

The color presentation is as close as possible to the monitor gamut, but the projector dynamics are not sufficient for the red light.

Blurry representation as a result.

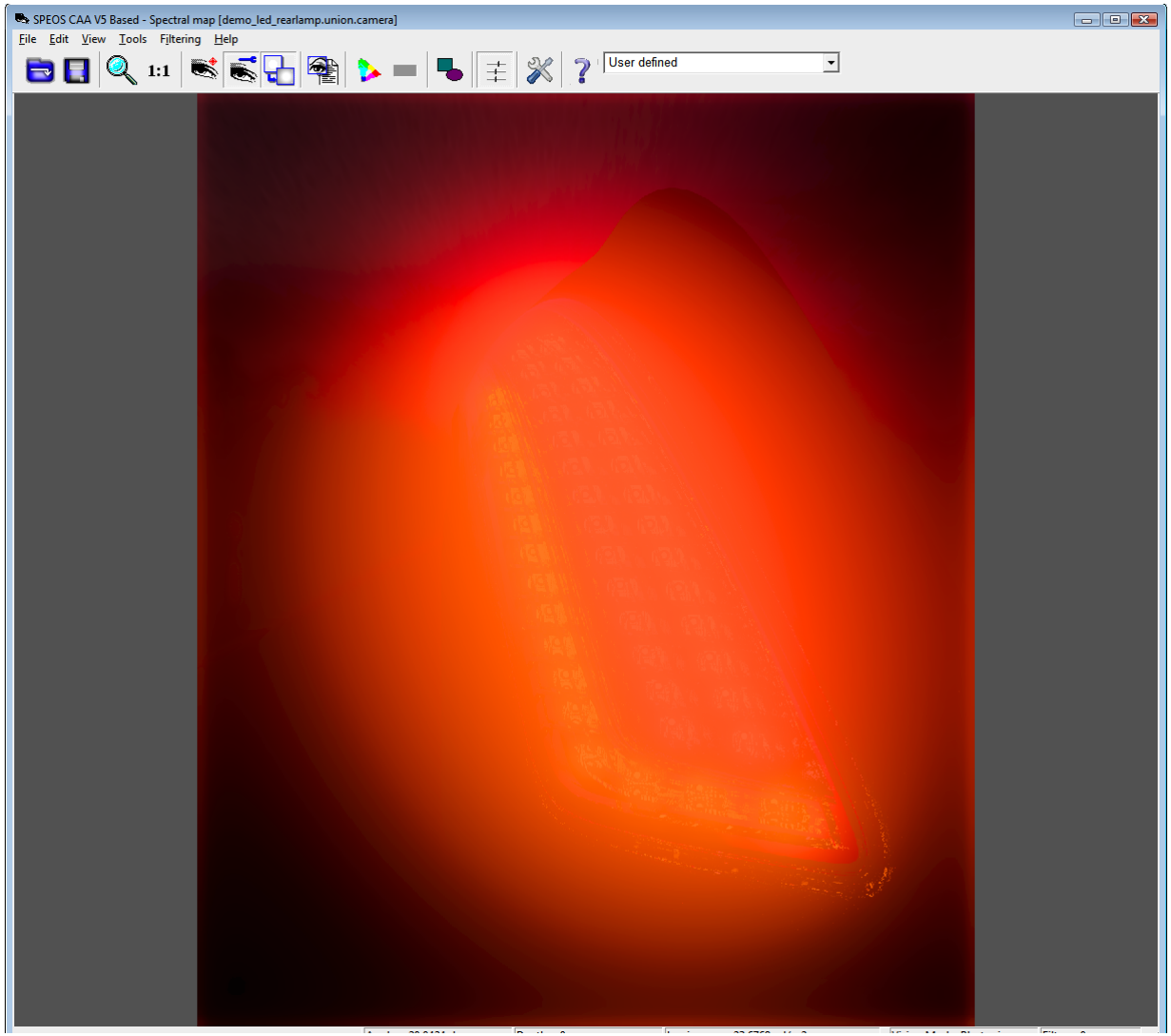


Glare Effect:
Vos, 1984

Display Mode:
Maintain Lightness and hue

Now the color presentation is not correct (the taillamp will not get white) but due to using the white pixels the dynamics is better.

Detailed Presentation, wrong color, close to digital cameras.



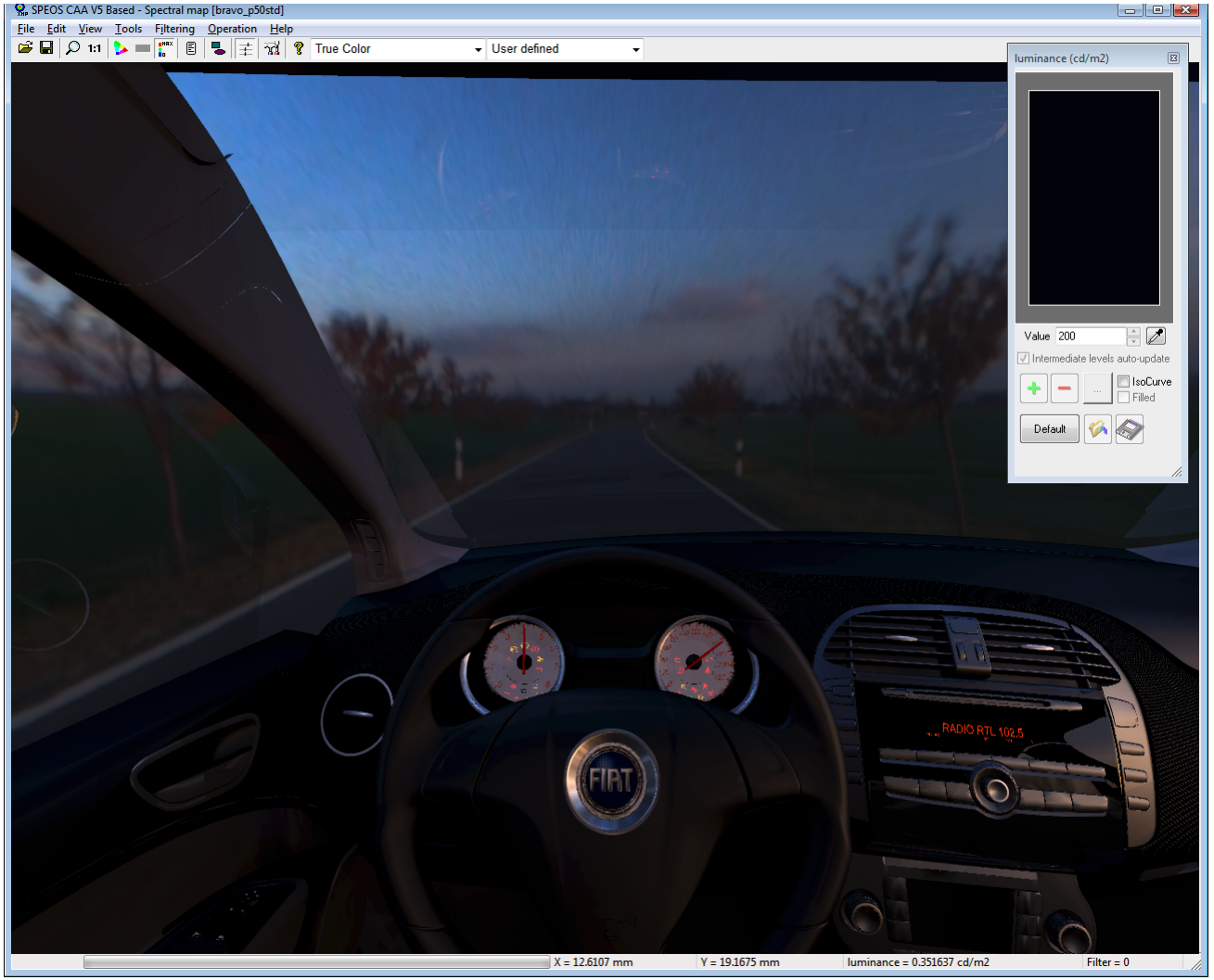
Glare Effect:
Holladay, 1926

Display Mode:
Maintain hue

A mix between of the previous settings.

Now, neither the displayed color nor the displayed dynamics are correct.

Conclusion:
Use Calibrated Displays !!

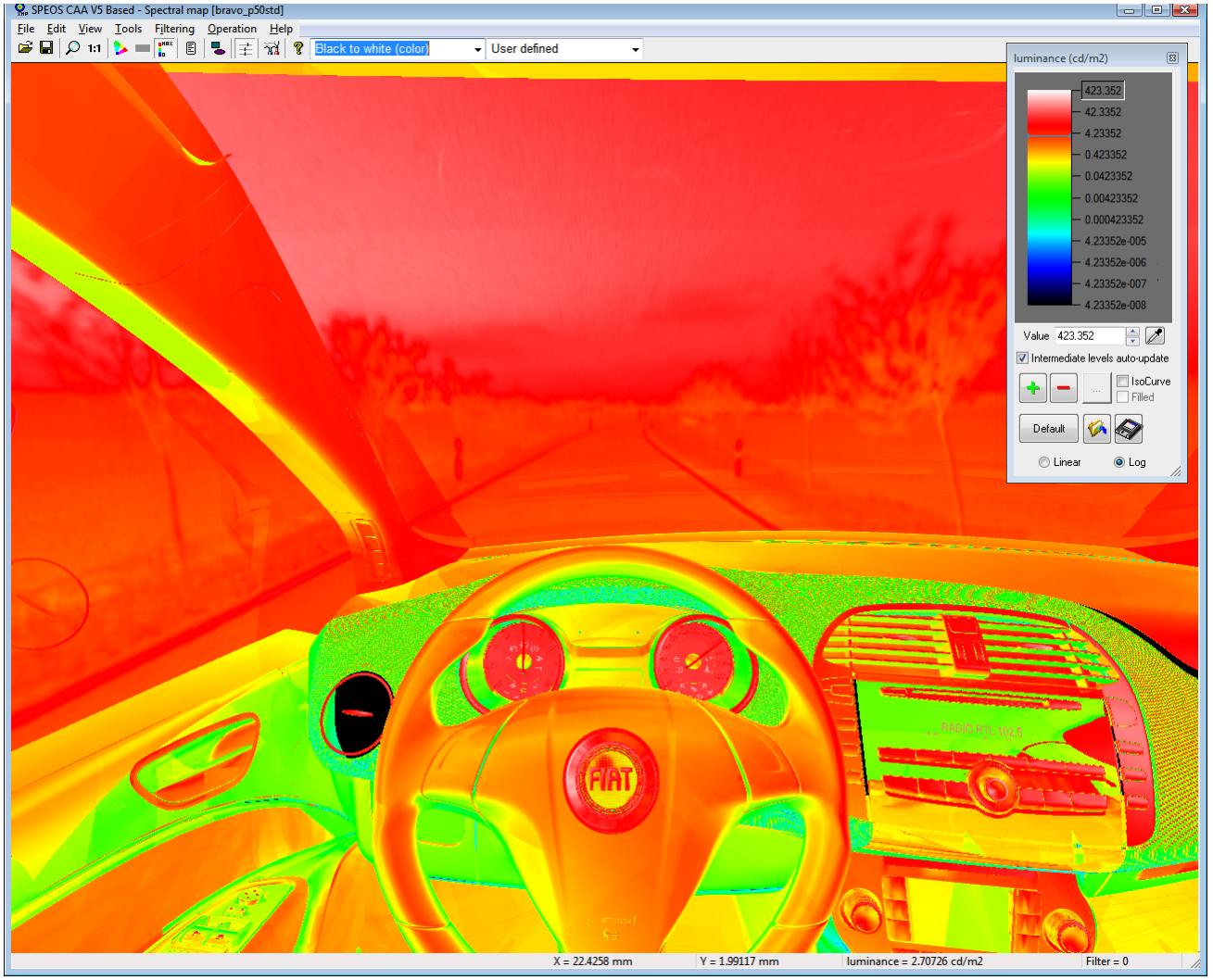


VP Lab (Virtual Photometry Laboratory)

Each Pixel contains information on Luminance and Spectrum.

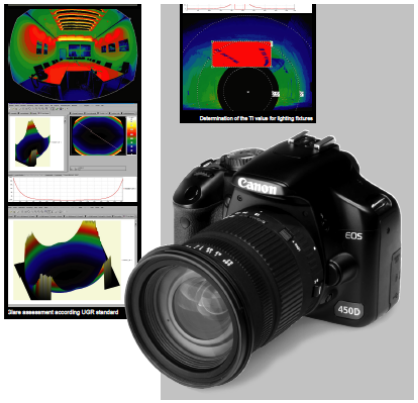
The result is normalized to the maximum of the screen luminance

Difficult to judge what the human eye will see!



VP Lab (Virtual Photometry Laboratory)

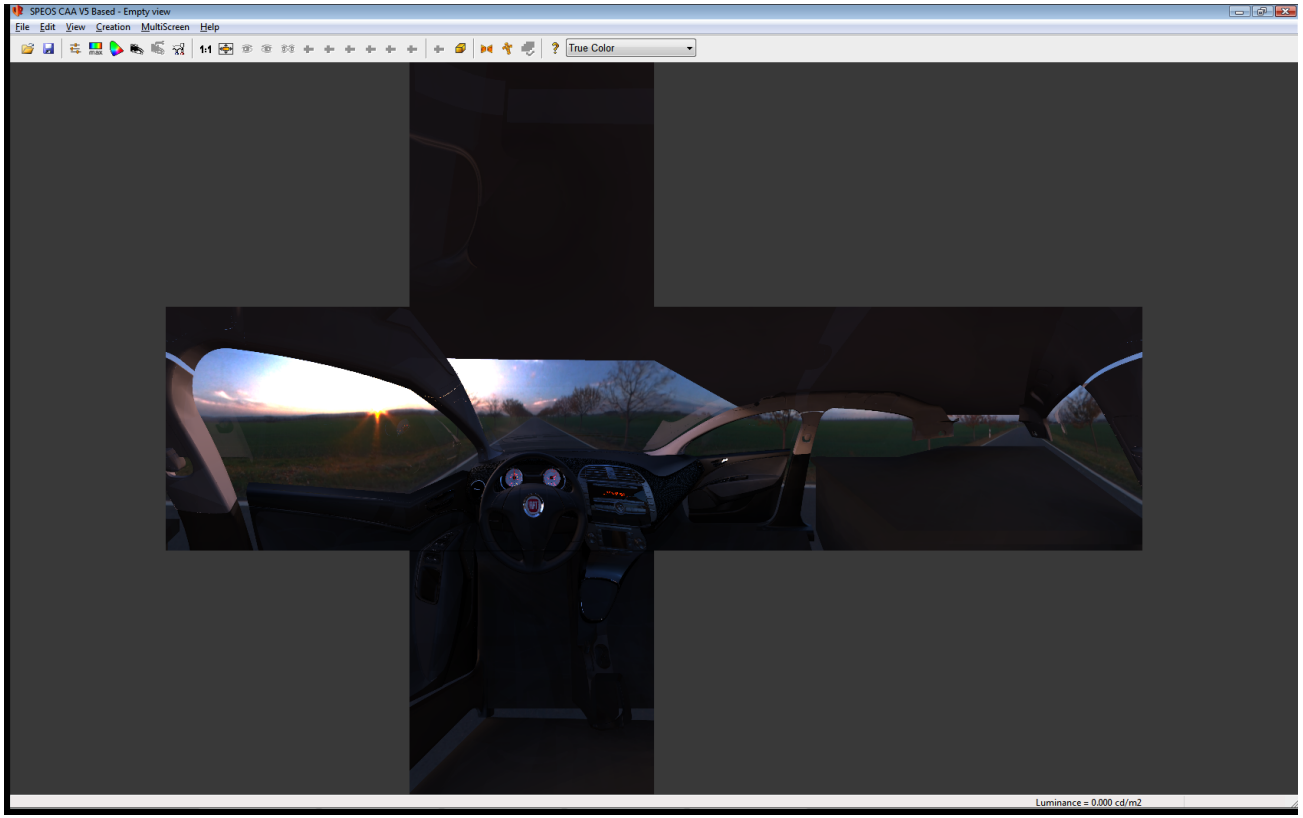
A false color view can be used to compare with measured data like with LMK Mobile.



HV Lab (Human Vision Laboratory)

Using this lab by the luminance in each pixel the human vision parameters like opening of the iris and glare in the vitreous humor are calculated.

Using a calibrated screen, the same contrast as seen with the human eye is displayed without scaling.



VR Lab (Virtual Reality Laboratory)

Using this lab it is possible to combine pre-calculated views into a cube or a video.

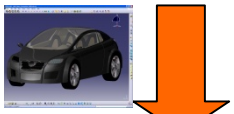
The luminance and spectrum values are exported to each pixel so the abilities of VP Lab and HV Lab are present in this application.

VR Lab (Virtual Reality Laboratory)

It is possible to change the drivers view and the lighting conditions interactively without doing new simulations.

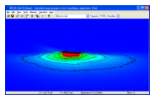
With one simulation it is possible to simulation daytime and nighttime conditions as far as different LED colors.

Real Time Simulators



Geometry

Analysis Results



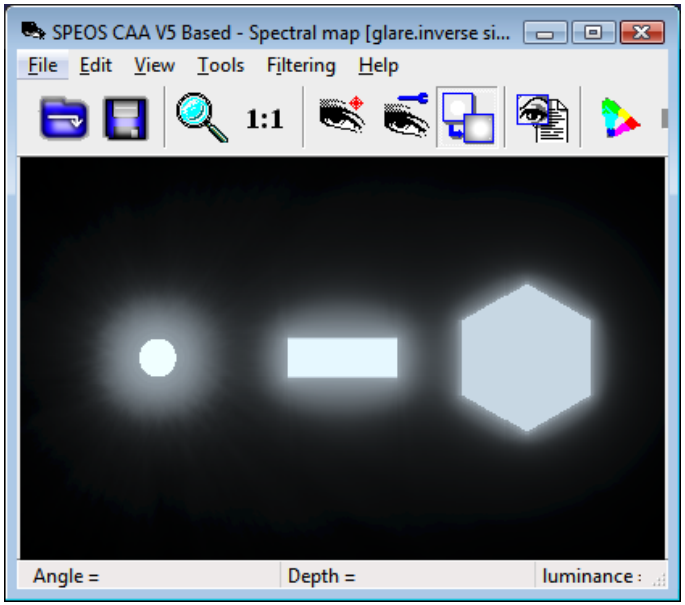
Measurements

OMS2 – Optical Bench

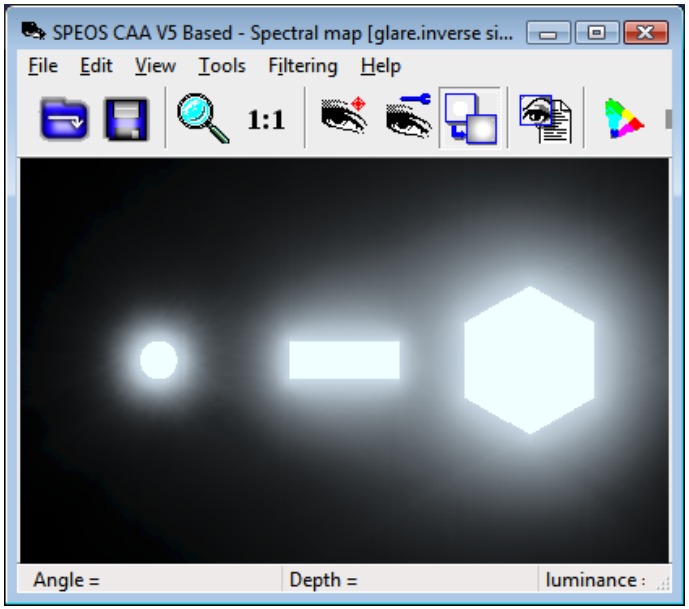
Connection the simulation results and geometry and measurements we can display the results with high precision in driving simulators etc.

Effect of LED light on human factors

Glare Effect on small light sources

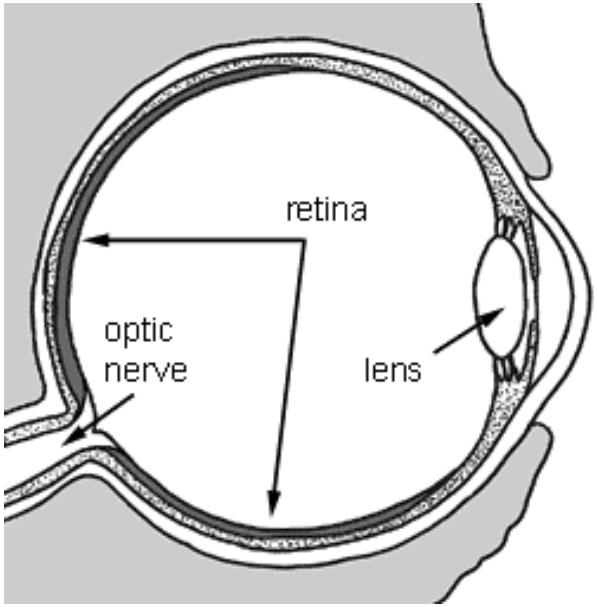


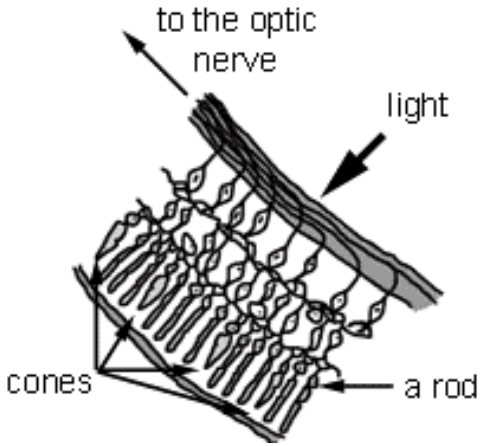
All the sources have the same optical flux in this image. We can see that the glare on the smaller light source is much higher, creating a nuisance to the human eye.

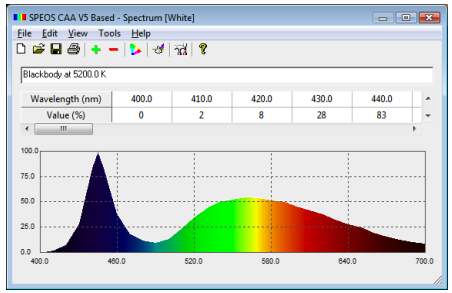


On identical Luminance (optical flux/surface) the glare effect (the loss of contrast from the source border to the black) is identical.

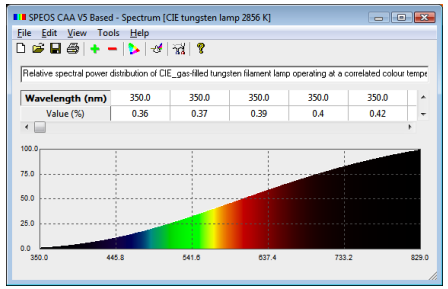
Glare Effect on blue light emission







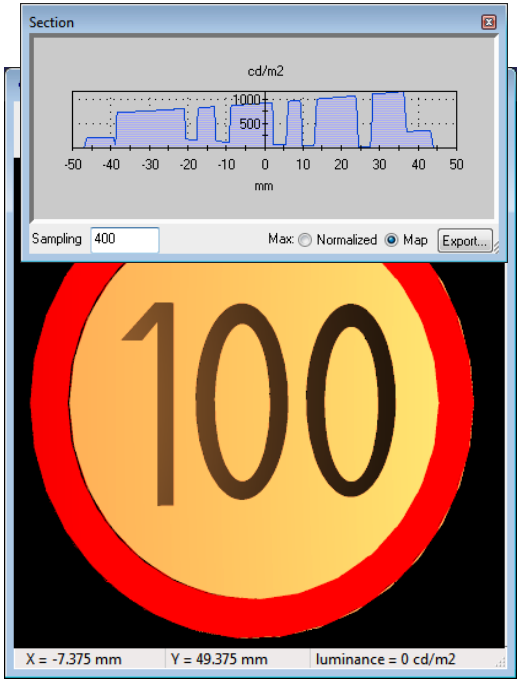
White LED spectrum



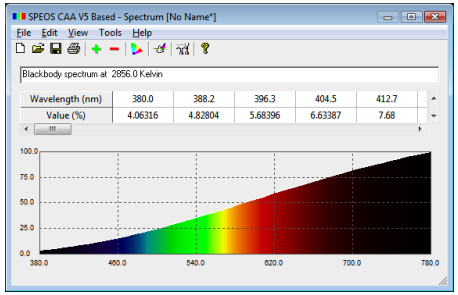
Tungsten Lamp spectrum

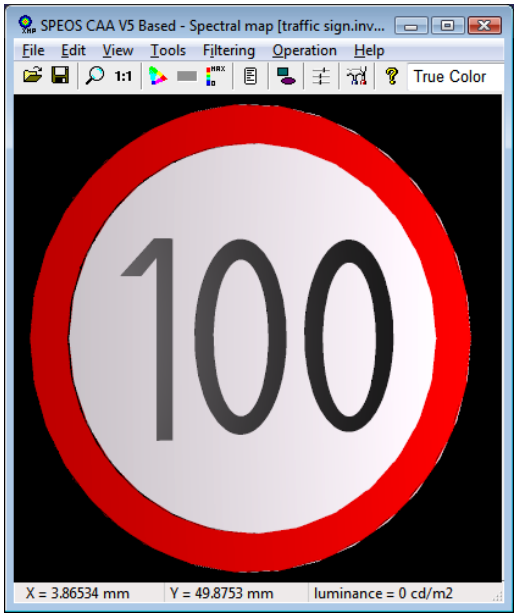
The cones in the retina are responsible for color vision. The rods are not sensitive to colors. The distribution of cones and rods on the retina is not homogeneous, there are only cones in the center of the vision and rods at the exterior of the vision field.
This is why white blue light (LED) is generating more glare compared to yellow white (Halogen) light.

Visibility of LED light



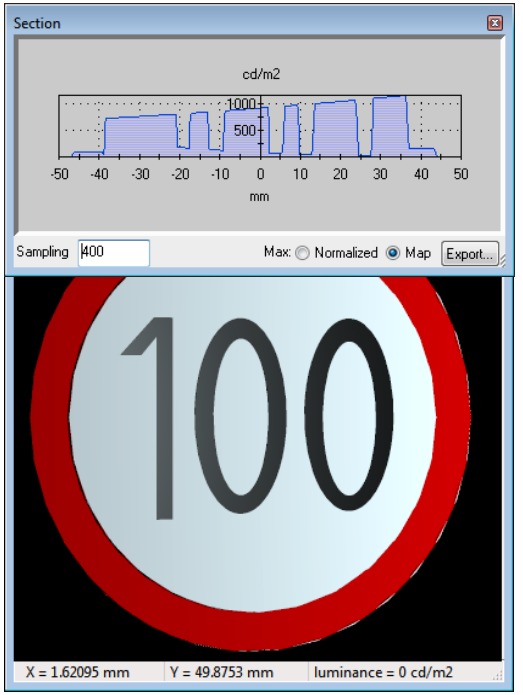
H7 Bulb



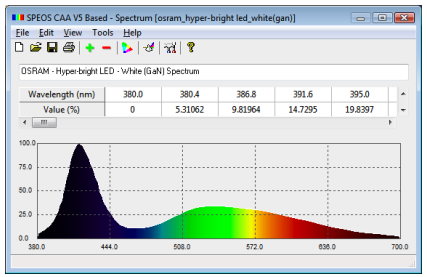


Daylight
6500K

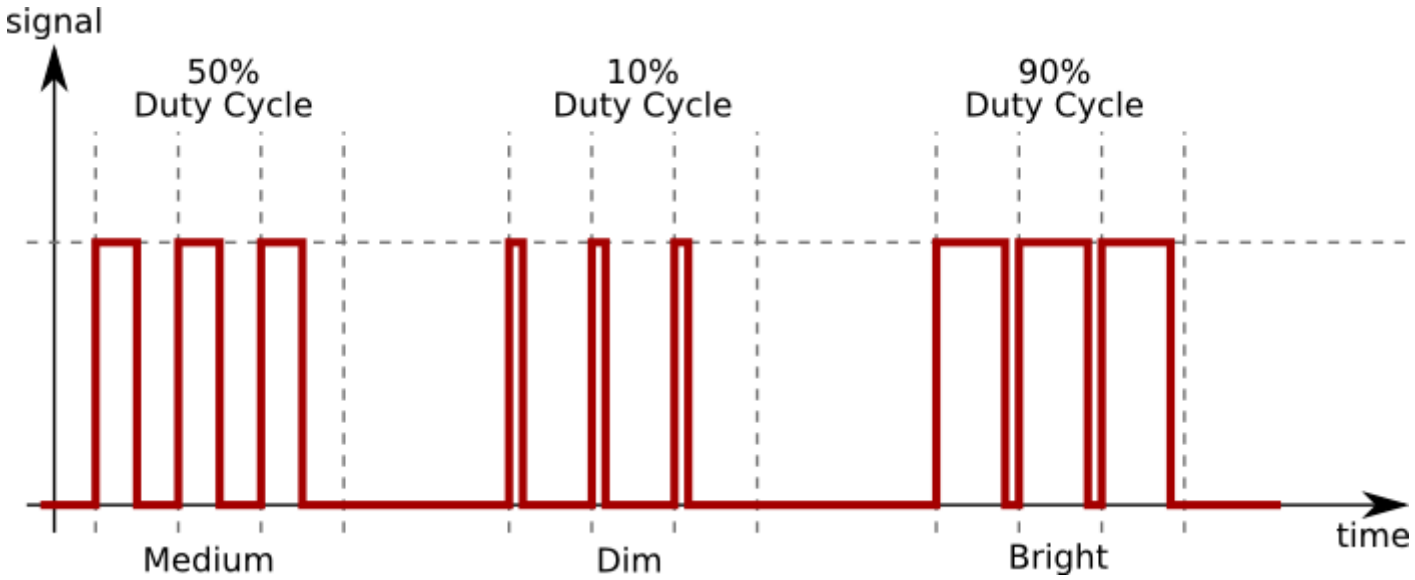
Visibility Analysis using different spectra – LED Light gives better vision and recognition



White LED



Fast switching LED signals (visibility and flickering)



To dim LED light a pulse width modulation (PWM) is used. Attention should be taken that the frequency of this modulation is not visible to the human eye in interior lighting, especially in the attention field (lateral to the vision direction) which leads to viewer stress.

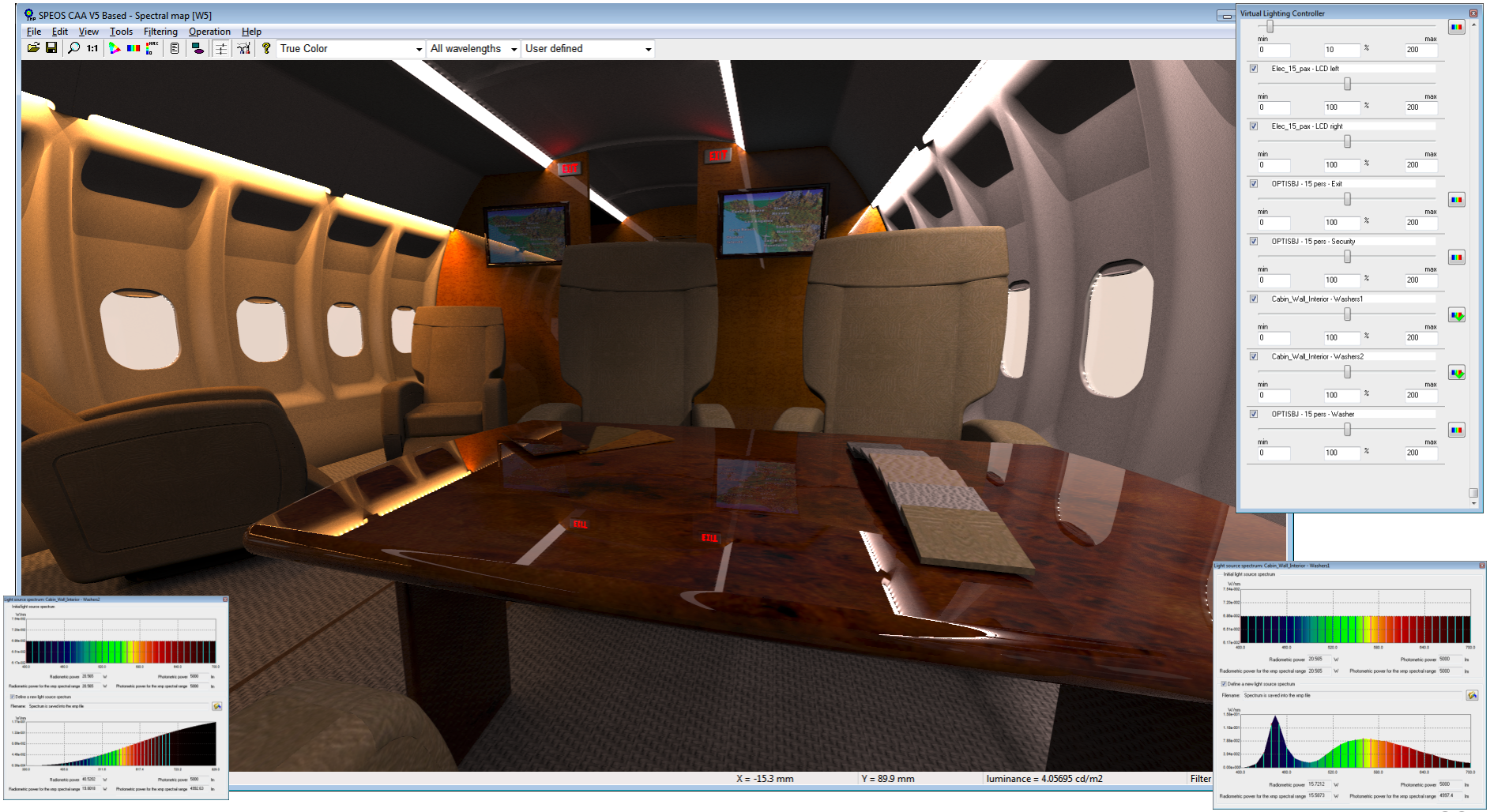
Color Contrast and legibility

- The legibility is not only depending on contrast, but also on colors.

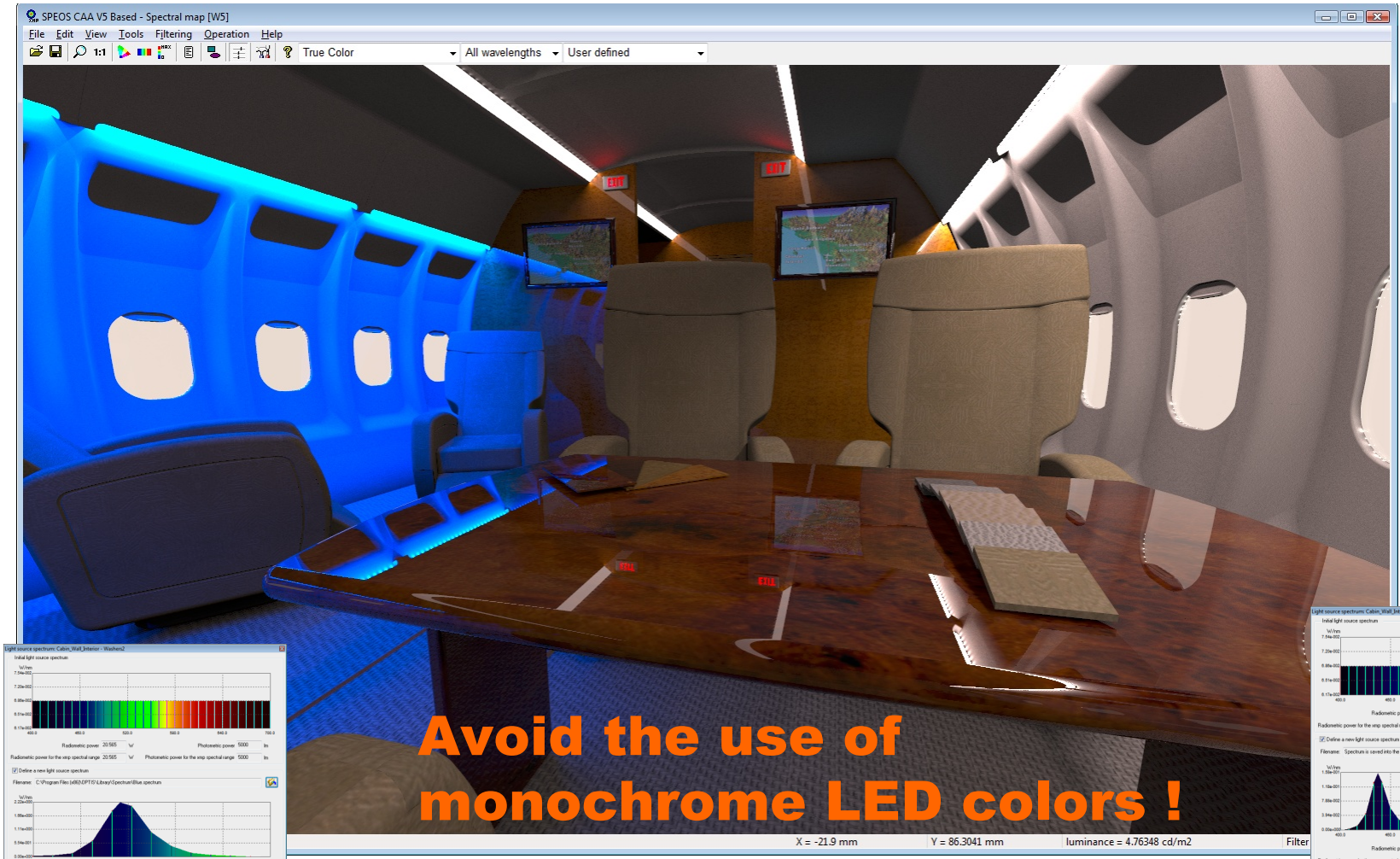
- The best is using black to white, passing to grey is still quite legible for the human eye

- There are worse things you can do to stress your readers

Influence of color on human factors



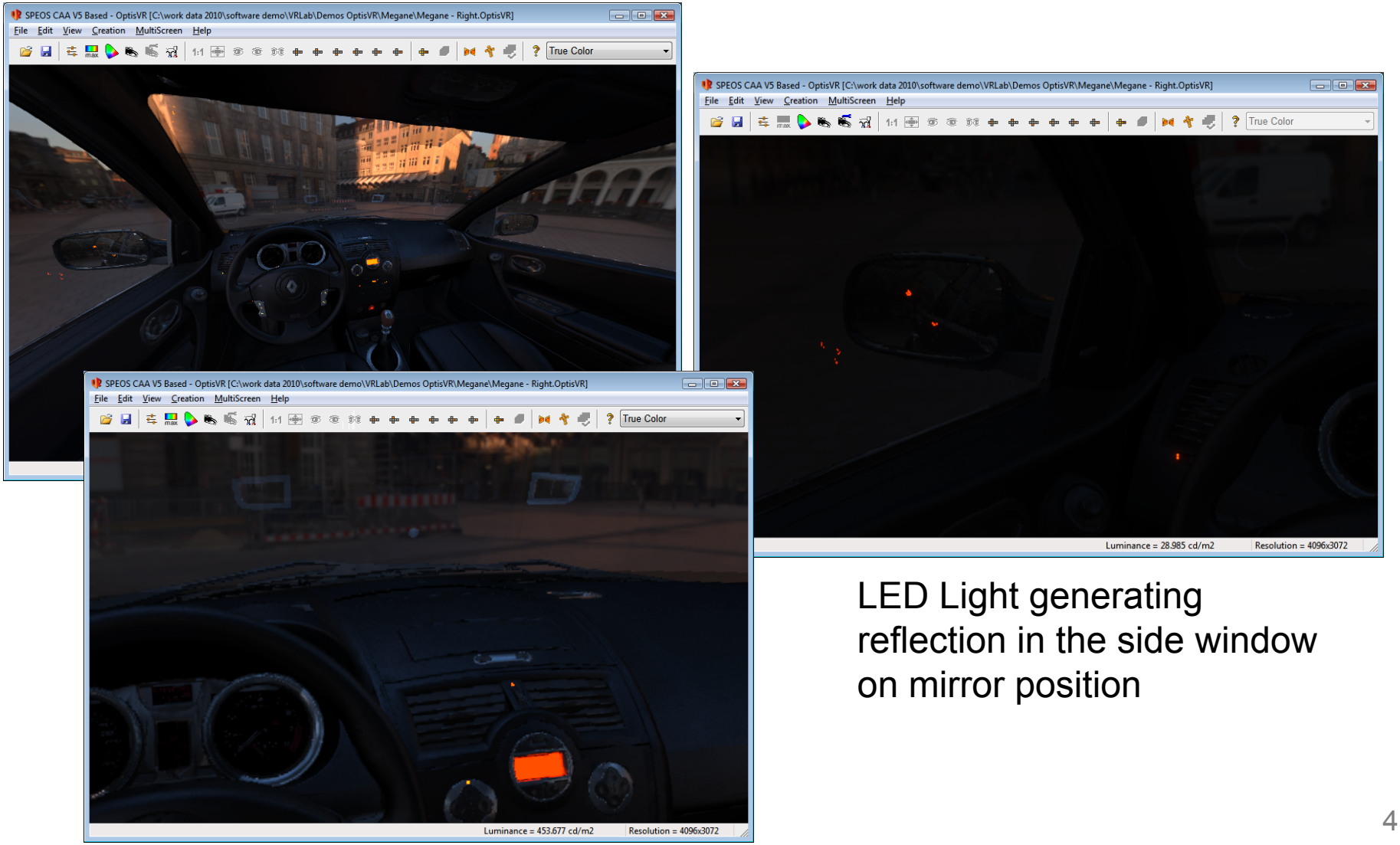
Influence of color to human factors



Optimization of car interiors for driver and passenger visual comfort

Demo Case Renault Megane – VR Lab Video

Demo Case Renault Megane – Reflection Study



LED Light generating reflection in the side window on mirror position

Demo Case FIAT Bravo – Reflection Study