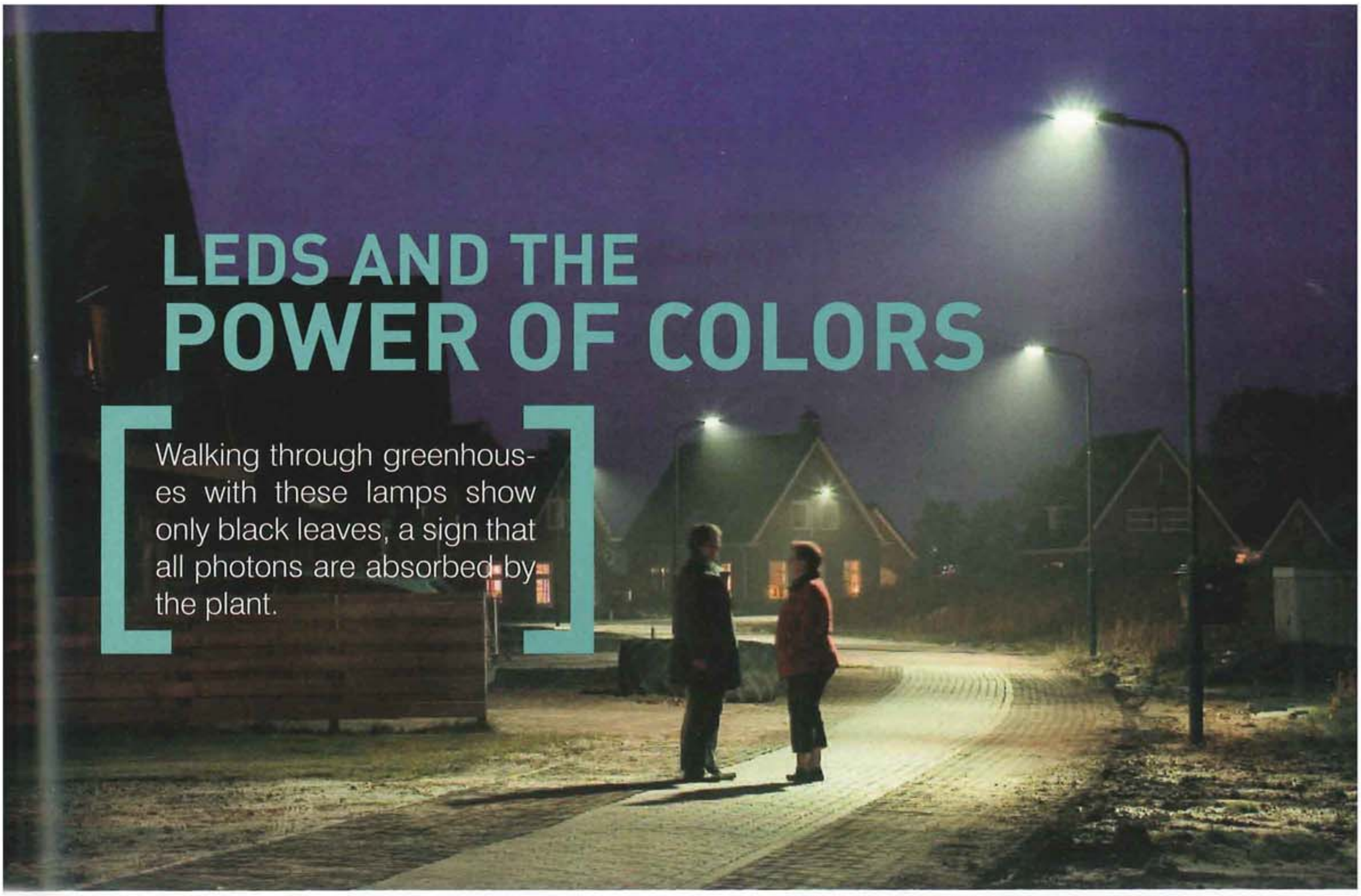
LEDS AND THE POWER OF COLORS



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Domestic area with 10W Lemnis streetlights

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Lemnis Lighting

Seeing colors trigger our senses and the effects are more complicated and effective than we realize. Color combinations are much more important in life than one suspects and not just because they bring the well known "color in life". Each and every little part of the spectrum has its own function and in combination with each other it opens a new world of hundreds of combinations and applications.

Colors for growth

Plants grow because of photosynthesis. Its the world's most effective energy conversion system and the reason that we can live on this planet. Plants absorb light to convert it in the photosynthesis process with hydrogen and carbon dioxide into nutrients and oxygen. Of all available colors in the spectrum a plant needs mainly the deep red part for this process. Recent developments make it possible to grow plants under LEDs in a very effective way. Walking through greenhouses with these lamps show only black leaves, a sign that all photons are absorbed by the plant. The energy reduction is enormous because only a small peak of the spectrum is to be generated. Savings up to 75% can be achieved compared with existing assimilation lighting. New developments based on the successful commercial introduction of LEDs in plant growth by Lemnis is production of bio fuels. The photosynthesis process in algae is up to 200x more efficient and is showing already promising results in combination with wind energy.

Better vision by spectral power distribution

The spectral composition of light strongly influences our vision. The eye contains 120 million rods and about 5 million cones situated in the center. Cones need a sufficient lighting level to recognize the different colors red, green and blue. At low lighting conditions the cones will not be fully activated and therefore reduce the color vision or when levels get low enough the colors will completely vanish. The 120 million rods are placed around the center of the eye and are much more sensitive.

Rods however, don't recognize colors. At daylight levels the highest eye sensitivity is at 555 nm. Under low light conditions the highest sensitivity for the rods shifts to 507 nm. which is a cyan greenish color.

The take-over of vision from cones to rods works by the intensity of the light. In darkness our eyes will only see with the rods which is called "scotopic" vision. In low lighting level applications like outdoor street lighting, both type of sensors, the rods and cones will be active. This is called mesopic vision. Light with a special spectral power distribution with threshold triggers for the cones allow increased color recognition at very low light levels.

One should realize that the CRI or Ra color standard is only valid under sufficient light conditions.

In practice outdoor lighting levels are almost never that bright that the maximum eye sensitivity is at the peak of 555 nm. The shift of eye peak sensitivity from 555 nm towards the 505 nm is caused by difference between rods and cones vision and is rated in a S/P ratio, Scotopic/Photopic or Rods/Cones. The higher the S/P ratio the better the contrast and peripheral vision.

Study by independent research laboratories indicate that the improved vision under high S/P ratio's is not only valid at low light levels but also under most interior light level conditions. Special spectral power distribution will affect the pupil size and with that the perception of light. The light intensities are no longer only perceived by the photopic luminous lux standard but more by the spectral power distribution.

Another condition for optimal vision is the best possible uniformity in intensity of the light. Think about walking in nature at full moon. The uniformity is here the key of good vision. The level is so low that we don't see any color

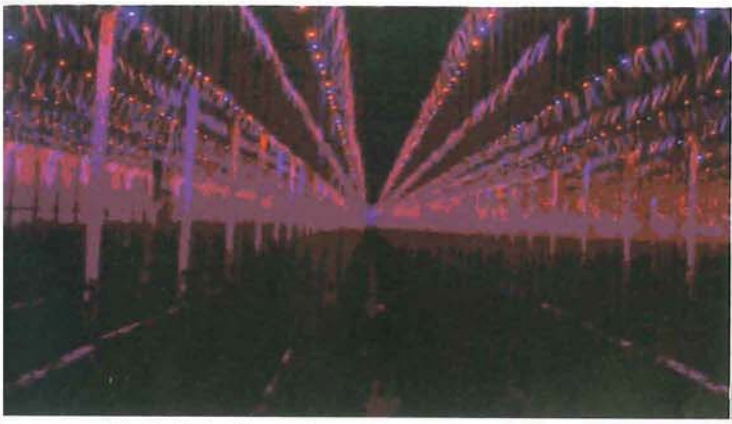


Fig. 1. Full photon absorbtion by plants

Fig. 2. Bigger leafs more biomass at 1/6 of energy

fig 3. Eye sensitivity characterized by light intensity parameter x

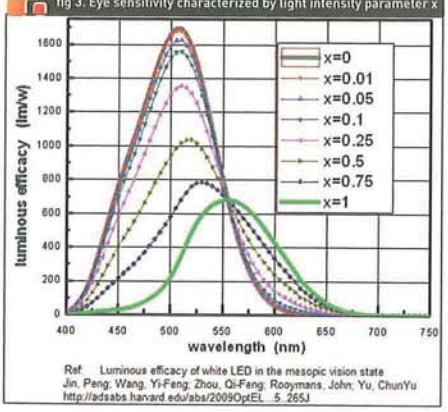
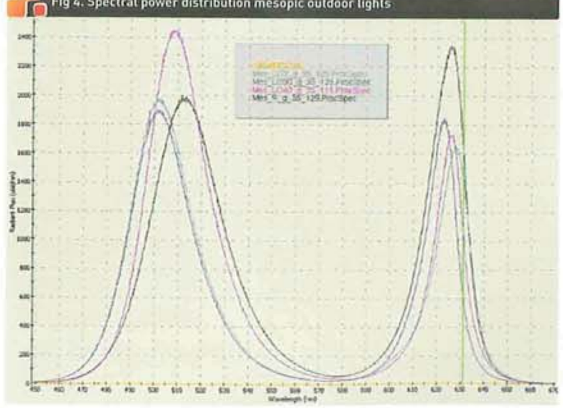


Fig 4. Spectral power distribution mesopic outdoor lights



but the light perception is great. The special secondary optics in Lemnis streetlights provide high uniformity and SPD triggers allow good color perception at low light levels.

Spectral manipulation of light can be seen as the tone control of light, analogue to the tone control of sound. The human ear is also not linear and responds physiologically. At low sound levels we don't hear the bass and high treble clearly anymore and music sounds flat. Applying an equalizer we are able to lift the bass and treble levels and manipulate the low level music's spectrum in such a way that we hear the same dynamics and color in the music as when it was played loud. By adjusting the spectral power distribution of light in a similar way we can experience bright colors even at low light levels.

Fig. 5 Regular white LED

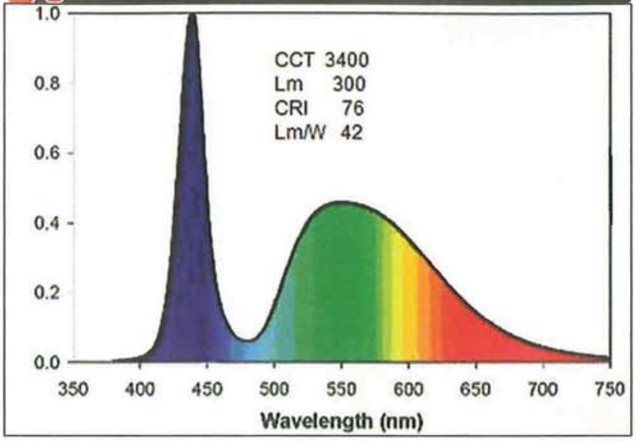
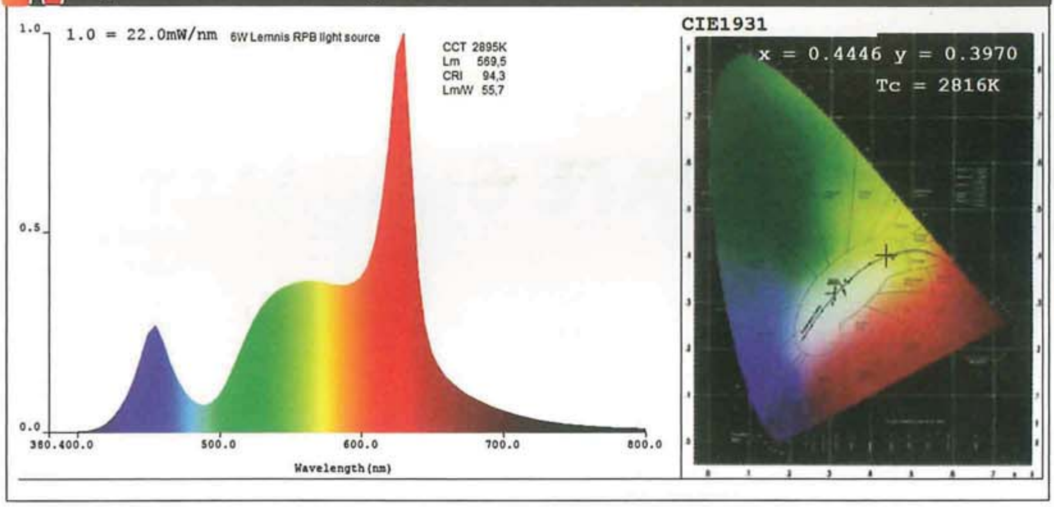


Fig. 6. Lemnis warm white light source 2900K- CRI 94



Lemnis LED light sources

Building the first mass production LED warm white incandescent replacement lamps in 2005 with RGB chips provided Lemnis good knowledge of S/P ratio's and spectral power distribution for further quality and vision improvements. The LED industry applies blue chips with 3P or 4P phosphors for white light. Such spectral distribution does not meet the characteristic of incandescent lamps which have a CRI of 100.

The blue component of regular white LED lamps is not found in incandescent lamps. Warm white light with high CRI is not possible based on the current white LED standard. The white/red hot filament of an incandescent lamp produces high output in the red spectrum. The Lemnis spectral distribution has also a threshold trigger in red resulting in a CRI up to 94 for mass produced light sources.

In this article we have seen the importance and effects of colors and the right combinations.

LEDs can produce efficiently red, orange, yellow, green, cyan, blue or ultraviolet light.
The use of fundamental colors is preferred above phosphor for lifetime advantages.

Lemnis LED applications are built with good knowledge of SPD and thermal management making the products efficient and sustainable. Colored Leds allow to play with the spectrum and a new era of understanding and utilizing light has just begun.