Light Pollution, Blue Light, Stress and Insomnia: Dark Sides of the LED Light?

Dr Laurent CANALE

CNRS Research Engineer, IEEE Senior Member
LAPLACE, Université de Toulouse, CNRS, INPT, UPS, Toulouse, France
118, Route de Narbonne, 31062 Toulouse Cedex 9, France

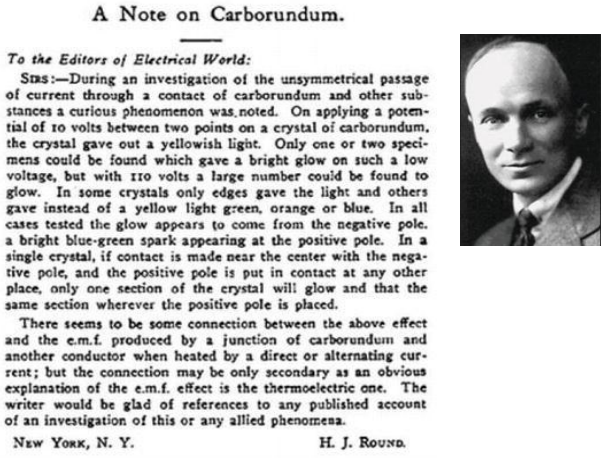
E-mail : laurent.canale@laplace.univ-tlse.fr

Abstract **-** During decades, for indoor applications, a bulb was replaced by the same bulb, 100W, 60W or less, incandescent or sometimes linear fluorescent, and only mattered the shape, the power or the type of socket... The LEDs is the ultimate home revolution in lighting technologies and, as every newcomer, it comes with its censors and detractors. Light pollution, photo-biological risk to the eye, environmental impact or insomnia are not exclusive to LED lamps; but its remarkable arrival, in a world where evolutions are discreet, focus questions and suspicions. In a world where nothing is all white or black and in which LED lighting is praised or hated, how do you share the true and the false? LED's advantages fill a long list… But is there any black side? Is there some inconvenient? What do you know about LED? And finally, what can it bring you? After an often unknown story of the LED, you will find some keys for you to be well enlightened, for your individual or collective well-being, at the scale of your home or a city, about light pollution, fauna and flora impact, about recycling and environmental impact and of course, human health.

Keywords **–** Light pollution, LED light, Lifetime, Lumen, Human impact.

I. A LED IS BORN

Working on wireless transmission, Cpt Henry Joseph Round was an English engineer from Marconi Company where crystals like Carborundum are used by these pioneers of radio. In 1907, he published a paper on curious observations : His Carborundum crystal (Silicon Carbide, SiC) emits some colored lights when he applied voltages between 10 to 100 V [1]. As the first to recognize the newborn, Joseph Round can certainly be considered the father of LED.



A Note on Carborundum.

To the Editors of Electrical World:

SIRS:—During an investigation of the unsymmetrical passage of current through a contact of carborundum and other substances a curious phenomenon was noted. On applying a potential of 10 volts between two points on a crystal of carborundum, the crystal gave out a yellowish light. Only one or two specimens could be found which gave a bright glow on such a low voltage, but with 110 volts a large number could be found to glow. In some crystals only edges gave the light and others gave instead of a yellow light green, orange or blue. In all cases tested the glow appears to come from the negative pole, a bright blue-green spark appearing at the positive pole. In a single crystal, if contact is made near the center with the negative pole, and the positive pole is put in contact at any other place, only one section of the crystal will glow and that the same section wherever the positive pole is placed.

There seems to be some connection between the above effect and the e.m.f. produced by a junction of carborundum and another conductor when heated by a direct or alternating current; but the connection may be only secondary as an obvious explanation of the e.m.f. effect is the thermoelectric one. The writer would be glad of references to any published account of an investigation of this or any allied phenomena.

NEW YORK, N. Y. H. J. ROUND.

Fig. 1. First known article about LED, Inset Cpt H. J. Round.

But the first to have built a LED prototype was Oleg Vladimirovich Losev, a young Soviet researcher in the 20s [2]. Thus, if the father of LED was Round, the mother who has delivered the LED was undoubtedly Oleg Losev.

Fig. 2. First LED patent and measurements, Inset O.V. Losev.

When Losev built his prototype, he didn't know the Round's work but he has not only built the prototype, he has done measurements and observe

light. But Losev is mainly known to be the first to link observation and physics principle using the new quantum theory of Einstein to explain how electrons can produce light without releasing heat and he calls this emission process “inverse photo-electric effect”.

In 1935, the French physicist Georges Destriau discovers the emission of light in zinc sulphide (ZnS) and he also first coined the word "electroluminescence" to refer to the phenomenon he observed [3]. In honor of the Russian physicist, he called this effect "Light of Lossew". Today, Georges Destriau is considered the inventor of electroluminescence.

In 1958, Rubin Braunstein and Egon Loebner patent a green LED made from a lead Antimonide/Germanium alloy but the shift to industrial application was made by Prof. Nick Holonyak in 1962 with development of the first practical LED [4]. This last was red lighting and used only for display applications. The early 70s have seen appearance of the yellow LED (George Craford, 1972) [5] and the blue and violet LED (Herbert Paul Maruska, 1972) [6]. But the last big step to the worldwide revolution for LED lighting applications was done by Shuji Nakamura, Isamu Akasaki and Hiroshi Amano in 1993 with a high power blue light emitting diode that was thus able to allow white lighting [7]. This story will probably continue with the next breakthroughs likely related to improving energy efficiency …

II. A LOT OF ADVANTAGES… BUT?

LEDs are attractive on paper : ten times more energy efficient, a lifetime forty times more long than incandescence (Fig. 3), they can be dimmed, switched on and off without life depreciation, and virtually unbreakable… Moreover, they are small, weight light and can be easily integrated in many applications. The combination of light and electronics was the key factor to open the road to the field of smart lighting and thus, to the “Internet of Things” …

But if the lighting was stilling the preserve of few global manufacturers during decades, this revolution opened also the door for electronic and with this, for many free-riders. A LED bulb is two parts : a light source and an electronic device required to adapt the main. This one leads to quality if they are well thinking and built with filters, highly integrated circuits, high efficacy… But these could be also replaced by few low cost compounds… While the first one of manufacturers must protect a brand image, the latter seek only to make the most of profit with low-end products. The first enemy of LED is not the technology but unscrupulous manufacturers. LED lamps are expensive products, but if an expensive bulb does not guarantee quality, a cheap price is often guarantees of poor quality.

Fig. 3. Comparison of common light source… All the same amount of light but not the same efficacy and lifetime! …

The second weak point of LED is the lack of knowledge of installers of this new product. Most of people think that LED is a cold light and this is false! The back side of an LED lamp is hot and the temperature is the Achilles heel of the LED technology! With an increase of temperature, the lifetime can decrease dramatically (Fig.4)! LEDs bulb can provide a real added value if you have the right product well installed.

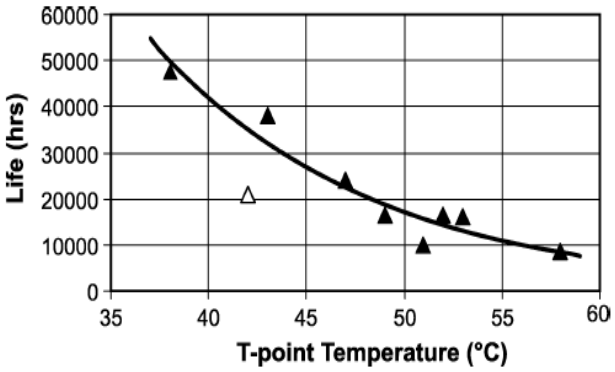


Fig. 4. Lifetime vs temperature for White Light LED [8].

III. NEW PARADIGMS & UNITS UPSIDE DOWN

A) Lumen… “Watt” out ?!

For decades, we have measured the amount of light emitted from a lamp through its electrical

consumption. Illogical but functional!... As long as it exists only GLS lamps... And fluorescent lamps compact appeared and LEDs... Incandescent lamps, removed from the market light was evaluated in "Watt equivalent" referring of a lamp that no longer exists. Time for a deep change had come, time to use light units for light, time to use light units to quantify light amount: the Lumen (Lm).

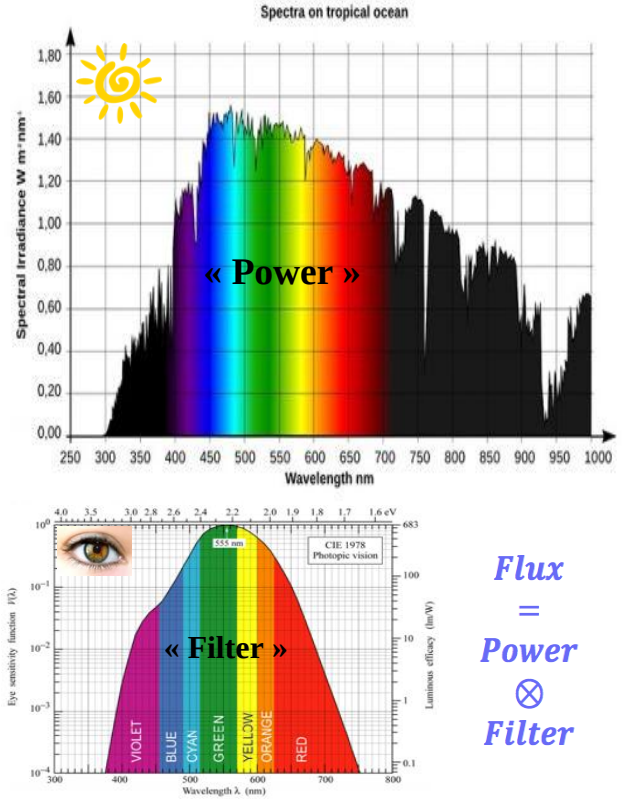


Fig. 5. Full sun spectrum at sea level, Human eye perception [9] and Lumen definition

Human eye works as a non-uniform filter. Thus the right measurement of light for a human eye is the full spectral irradiance viewed through this filter: this is Lumen.

B) Color temperature…

Defined as the light emitted by a heated black body and measured in Kelvin. When you heat a piece of steel, it becomes red at 1500K (1500 - 273.15 = 1226.85 °C) and then, you have a warm light… But if you increase the temperature up to 6000K, you will see a blue light emission, and then have… a cold white light! Human paradox linked to popular perception: fire is orange-red and is warm, ice is blue and cold. And this parameter is very important for well-being, sleeping and circadian cycle…

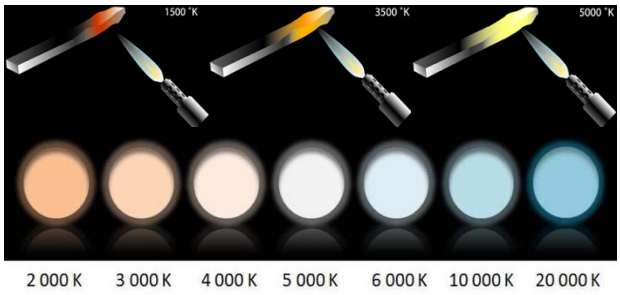


Fig. 6. Color temperatures, from the "warm" white to the "cold" white

C) Color Rendering Index (CRI or Ra)

The last very useful parameter is the Color Rendering Index (CRI). The CRI is an index that evaluate the capacity for a light to render right colors. Natural Light (Sun) have a CRI of 100. No CRI means that no color can be recognized.

IV. LIGHT POLLUTION

Light pollution may seem to have little impact in relation to sea pollution or air pollution from exhaust fumes. And we can think that seeing a beautiful starry sky is only a pleasure or luxury ... But light pollution is much more pernicious than we think at first. It can affect the fauna and the flora but also the human health. And the perception of the stars is also a good indicator to awaken our collective unconscious on our energy consumption because the light pollution is also the reflection of a big waste of visible energy.

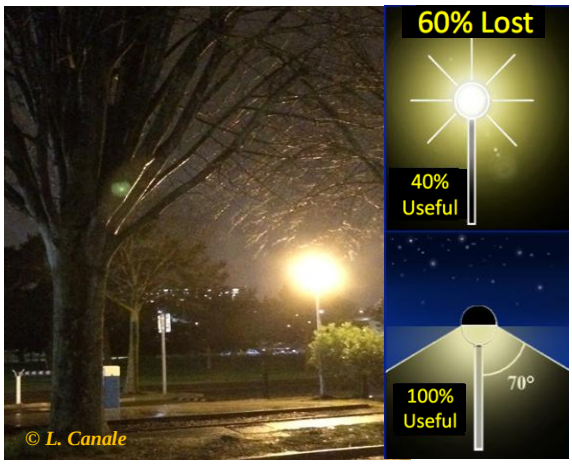


Fig. 7. Right, worst example of public lighting; left, simple solutions exists

And light pollution also impacts the fauna and flora and the consequences are not well known but a real ecological imbalance is observed. Only the full moon already affects the activities of insects (Fig. 8), so artificial lighting at night, much more… For

example, nocturnal pollinators are affected by street lighting, which can have an economic impact on crops. And the list of examples could be long for fish, birds, insects, bats, mammals : a lighted bridge is a barrier for eels, light cities impact migrations of birds, street lighting disturb reproduction.

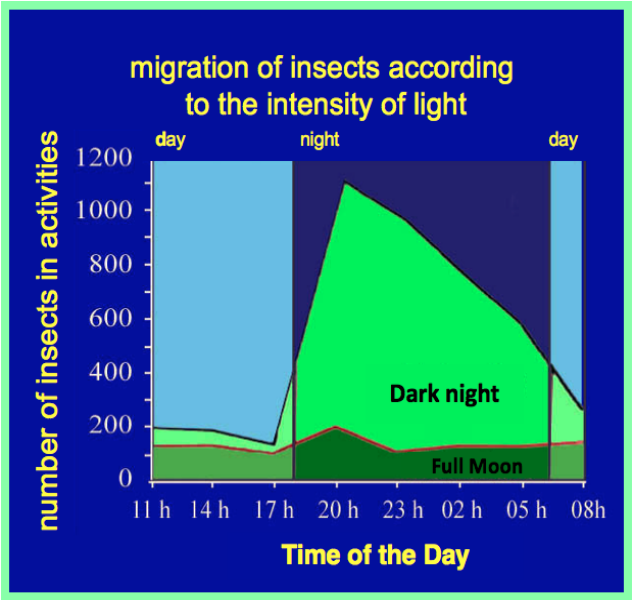


Fig. 8. Effect of the full moon on insects activities (Norman Anderson, Entomology Dept Oregon State Univ.)

Artificial lighting disrupts reproduction and ecological balance but solutions exist: Dark corridors and well-thinking lighting are solutions among many others ...

V. HUMAN IMPACT

A) Human eye and "Blue Light Hazard"

LEDs emit at a peak in blue and our eye is particularly sensitive to this wavelength. That is true. In addition, our iris does not react in the blue and remains largely open for this color. With age, for people over 18, the lens becomes yellowish and functions as a filter, but it is very clear for younger people. We could therefore conclude that LEDs are dangerous for our eyes ... The blue sky is it dangerous for our eyes? No. So what does that mean?

It means that all must be thinking in term of time and luminance (Fig. 9). That true for all light sources (even the sun!) and not only for LEDs…

But blue light plays another role in a much more subtle way on the wakefulness, the sleep and the circadian cycle…

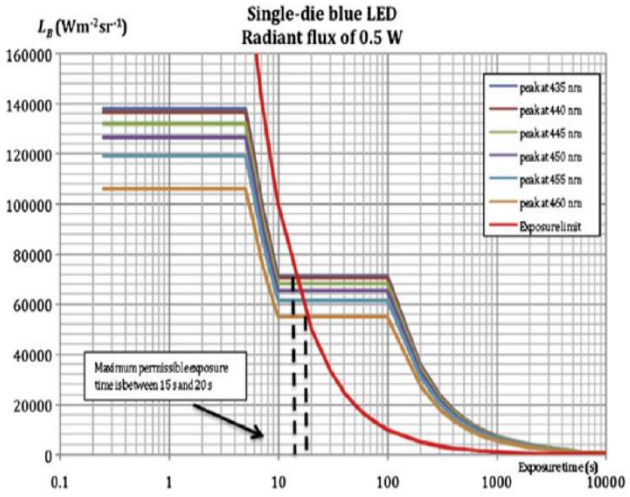


Fig. 9. Luminance VS exposure time to light / maximum permissible exposure without damage.

B) Circadian Cycle, wakefulness and sleeping

The blue light received by our retina plays a fundamental role in the regulation of our circadian cycle by the production of cortisol and melatonin (Fig.10). This last molecule is also known as the "sleep molecule" ...

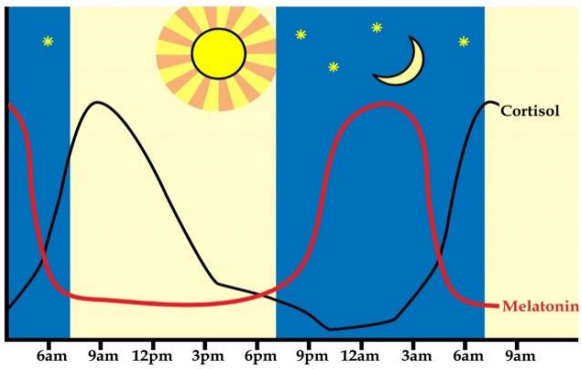


Fig. 10. Blue light works as a signal to produce or cut the melatonin or the cortisol

The effects of blue light are so important on wakefulness and sleep that a laboratory study of "sleep, attention and neuropsychiatry" (CNRS / Bordeaux Segalen University) has shown that it is as effective as coffee [13]! (Fig. 11)

But laptops, smartphones, digital tablets… emits a spectrum with a wide part in the blue… That's why sleep is disturbed when we still in front of this tools... But if you need to stay awake, unlike coffee, once the lights go out, the production of melatonin returns after about 30 minutes.

Fig. 11. Blue light effects on wakefulness… that improves motorway driving [13].

VI. CONCLUSION

LED lighting is probably the spearhead of one of the most important revolutions of recent years. With it, interconnectivity, smart lighting and smart cities become possible because street lighting could be one of the major communication network. Above all, they offer the enormous advantage of being able to adapt to all situations, to be easily controllable and to be able to switch on and off at will. As long as the right laws and standards are in place and the bad products can be removed from the market, their long life and low energy consumption also make them an environmentally friendly product.

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