Energy Saving in the Implementing LED Luminaries for Internal Lighting

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Abstract - **Light Emitting Diodes (LED) has begun popular in the use of lighting sources for instant in the applications of traffic light, signboard, cars lamp, and not except for general lighting such as for indoor lighting applications. Rapid improvement in LED technology which some of it can provide the light brightness up to 150 lm per LED with very good efficiencies. As stated in the previous finding or research, the LED that been used for general lighting sources can provide approximately equivalent light output of conventional lamp with only requiring half of the input power demand. This paper present the potential of LED lumnaire for indoor lighting applications and focused on energy saving. The continuous improvements of LED technology gives a lot of advantages for lighting system especially in terms of less energy consumption and reduce maintenance cost. Therefore, there is a great potential to replace the conventional lighting with LED lighting sources for indoor applications.**

Index Terms-- **LED Lamp, general lighting, energy saving.**

I. Introduction

LED technology for lighting applications has the potential for wide-scale use and large energy savings. During the last hundred years, electric lighting sources have gone through a series of technology transition that from early carbon filament lamps to the ever present tungsten filament incandescent lamps to the use of plasma discharge sources such as the fluorescent lamp or pressure sodium vapor (PSV). LED lighting also called solid state lighting (SSL) is bringing a new light source with different operating characteristics to the market.

LEDs use solid state semiconductor technology similar to those used in modern microprocessors. The parts of an LED are two semiconductor materials layered on substrate and powered by a low direct-current voltage; electrons released from the negative n-type layer combine with holes from the positive p-type. When electron-hole pairs are combined, a photon of light is emitted from the active layer. The semiconductor is often called a chip. The chips can be packaged in a variety of optical refracting forms to enhance the light output. The most common type has been the bullet-shape (T-1) that encases the chip in a 5 mm epoxy package. Current advances in chip packaging configurations now allow for improved directional control of the light output, better thermal management, and overall flexibility in design of light fixtures.

LED was first introduced in the early 1960s as indicator light and had efficacy of only 0.01 lumens per watt. By the 1980s, red LED performance had increased to more than 20 lumens per watt, and today produces more than 50 lumens per watt [1]. LEDs are now used in a multitude of applications and are available in several colors and packages. Industry experts expect continued improvement in light output and cost effectiveness of LED lighting. LED manufactures expect that LED efficacy will ultimately be able to achieve a goal of 150 to 200 lumens per watt in the future [2].

LED have many advantages over the conventional electric light sources, including low power requirements, long lifetimes, small size, optical control, and operating characteristics. Well known, the LEDs are requiring low direct current voltage and low power to operate. This ultimately results in reduced energy use. In many applications where LEDs are used today, the energy savings are at least 50 percent, and may up to 90 percent for the applications where they replace incandescent bulb. LED manufactures claim lifetimes of up to 100 000 hours with less than 40 percent lumen depreciation after 100 000 hours of operation [3], [4], and [6]. This is much greater than the operating life of conventional lighting such as incandescent and Fluorescent lamp which are normally 2500 hours and 13 000 hours respectively. Table 1 present the features of incandescent bulb and fluorescent lamp while Fig. 1 shows the lumen output performance along the operating time for several lighting sources.

TABLE 1
FEATURES OF INCANDESCENT BULB AND FLUORESCENT LAMP

Lamp	Watt	Output Lumen (Lm)	Efficiency (Lm/W)	Life (Hours)
Incandescent	60	850	14	2500
	100	1700	17	2500
Fluorescent	18	1030	57	13 000
	36	2600	72	13 000

Besides that the LEDs have been referred as the ultimate light point source. This offers product designers and integrators flexibility in their form and design for a wide range of products. LEDs in the miniature lamp market such

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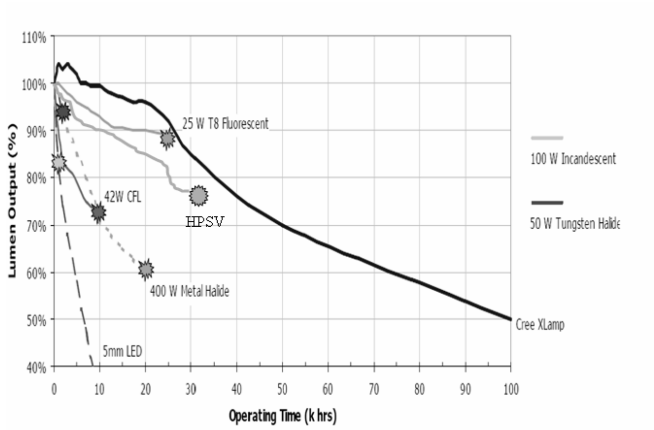
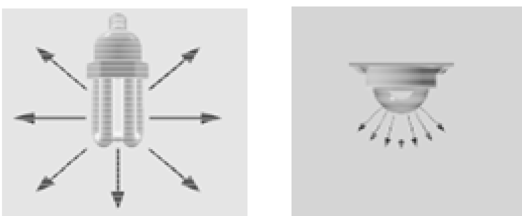


Fig. 1: Lumen output performance of several lighting sources

as use in automotive panel display lighting and rear cluster lighting is well established and growing. The small LED size also allows mixing of different colors in small areas to meet specific optical need. In addition, LEDs offer the benefit of greater optical control due to their small size packaging options. LED fixture efficiencies can be in the range of 80 to 90 percent which the typical fixture losses of conventional lamp are in the range from 40 to 60 percent as shown in Fig. 2 [5]. Thus, an LED light output does not have to be as high as a conventional light to achieve the same coverage. LEDs also have favorable operating characteristics where the light do not require any strike time which means it is instantly come on and off without affect the lifetimes.



(a) (b)

Fig. 2: The output light (a) Conventional lamp (b) LED

II. SOLID STATE LIGHTING IMPROVEMENTS

The SSL technology will follow the generally recognized model of technology advancement over time. Based on an anticipated performance target, new technology generally achieves that target by improving exponentially at the first, then linearly, and end with asymptotically. This type of improvement performance is referred as S-Curve performance as shown in Fig. 3. For the first stage, there is an exponential performance improvement as SSL emerges from its invention period. In the second stage, SSL technology improves linearly as continued R&D investment builds on prior breakthroughs and advances the technology. While in the third stage, the technology asymptotically approach 100 percent of its target value, as it becomes a mature technology with limited potential for improvement.

Technology improvement S-curve were developed for SSL sources analyzing three critical consumer parameters there are efficacy (lumen per watt), lamp price, and lamp life.

With the technology improvement and a lot of investment from industries, the development of SSL performance based on color rendering index (CRI) in terms of efficacy and lamp life could be accelerated rapidly while reducing the LED cost. These can be illustrated in the graph as shown in Fig. 4.

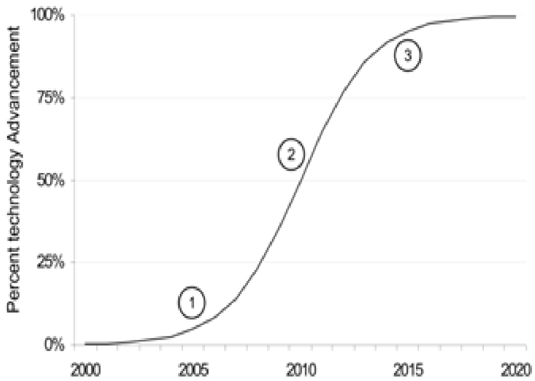


Fig. 3: The S-Curve of LED Technology improvement

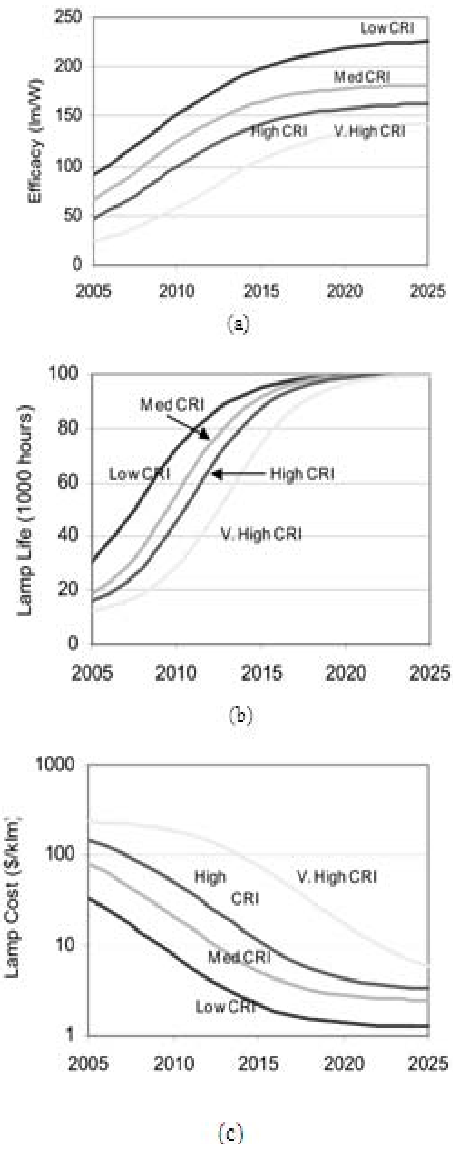


Fig. 4: SSL Improvement Based on CRI (a) Efficacy, (b) LED Lifetime, and (c) LED cost

III. WHITE LED FOR GENERAL LIGHTING

A combination of red, green and blue LEDs can produce the impression of white light, though white LEDs today rarely use this principle. Most white LEDs in production today are modified blue LEDs which consists of GaN-based and InGaN-active-layer LEDs emit blue light of wavelengths between 450 nm and 470 nm. This InGaN-GaN structure is covered with a yellowish phosphor coating usually made of cerium- doped yttrium aluminium gamet (Ce^{3+}:YAG) crystals which have been powdered and bound in a type of viscous adhesive. Fig. 5 illustrates the spectrum of white light. The LED chip emits blue light, part of which is efficiently converted to a broad spectrum centered at about 580 nm (yellow) by the Ce^{3+}:YAG. Since yellow light stimulates the red and green receptors of the eye, the resulting mix of blue and yellow light gives the appearance of white that resulting shade often called lunar white. This approach was developed by Nichia Corporation and has been used since 1996 for the manufacture of white LEDs.

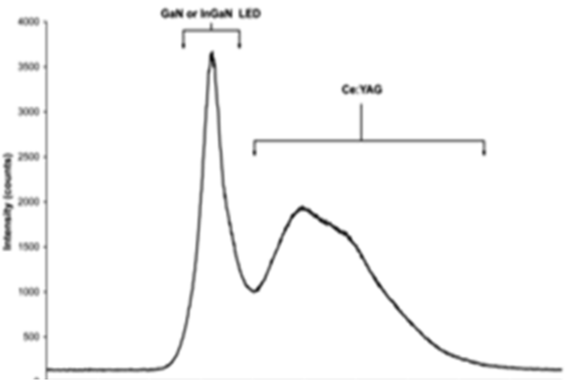


Fig. 5: The Spectrum of White Light LED

The pale yellow emission of the Ce^{3+}:YAG can be tuned by substituting the cerium with other rare earth elements such as terbium and gadolinium and can even be further adjusted by substituting some or all of the aluminum in the YAG with gallium. Due to the spectral characteristics of the diode, the red and green colors of objects in its blue yellow light are not as bright as in broad-spectrum light. Manufacturing variations and varying thicknesses in the phosphor make the LEDs produce light with different color temperature, from warm yellowish to cold bluish; the LEDs have to be sorted during manufacture by their actual characteristics.

White LEDs can also be made by coating near ultraviolet (NUV) emitting LEDs with a mixture of high efficiency europium-based red and blue emitting phosphors plus green emitting copper and aluminum doped zinc sulfide (ZnS:Cu, Al). This is a method analogous to the way fluorescent lamp. However the ultraviolet light causes photo degradation to the epoxy resin and many other materials used in LED packaging, causing manufacturing challenges and shorter lifetimes. This method is less efficient than the blue LED with YAG:Ce phosphor, as the stokes shift is larger and more energy is therefore converted to heat, but yields light with better spectral characteristics, which render color better. Due to the higher radiative output of the ultraviolet LEDs than of the blue ones, both approaches offer comparable brightness. The newest method used to produce white light LEDs uses no phosphors at all and is based on homoepitaxially grown zinc selenide (ZnSe) on a ZnSe substrate which simultaneously emits blue light from its active region and yellow light from the substrate A new technique developed by Michael Bowers, involves coating a blue LED with quantum dots that glow white in response to the blue light from the LED. This technique produces a warm, yellowish-white light similar to that produced by incandescent bulbs or fluorescent lamp [3].

IV. THE POTENTIAL FOR ENERGY SAVING

Since, the level of reliability, efficiency, lifetime, and lamp cost of LEDs are much related to energy saving, thus the main point discussed here is comparison of energy consumption of LED lamp against the conventional lighting especially incandescent bulb and fluorescent lamp. Well-known, the efficacies of incandescent and fluorescent lamp are not improving much with time, while LEDs are improved rapidly by time to time as discussed in Section II. For instant, nowadays the highest efficiency of LEDs that are available in the market can reach up to 100 lumen/LED and 150 lumen/LED with forward voltage of 3.3 V and forward current of 350 mA produced by CREE and Philips respectively. With these characteristics, the energy consumption for LED lamp could be reduced by at least 50 percent compared to incandescent bulb and up to 50 percent if compared with the fluorescent lamp at the same level of luminous flux. In addition, the LED can provide up to 100, 000 hours of useful lifetime before they gracefully degrade below 40 percent of their initial light output. That is equal to 11.4 years if left on continuously. However, in most lighting scenarios, the lighting sources are switched on and off regularly. The switch off period can extend the lifetime of the LED well past six decades as shown in Fig. 6. While, Fig. 7 illustrates the annual energy consumption of T-8 36 W fluorescent lamp and 19 W LED lamp for 50 percent energy reduction.

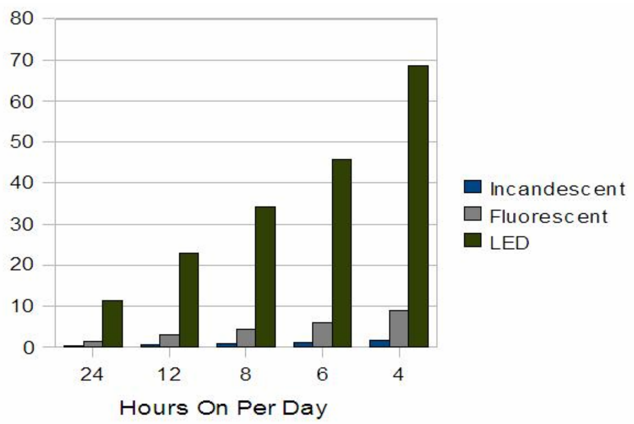


Fig. 6: Lifetime of lighting sources.

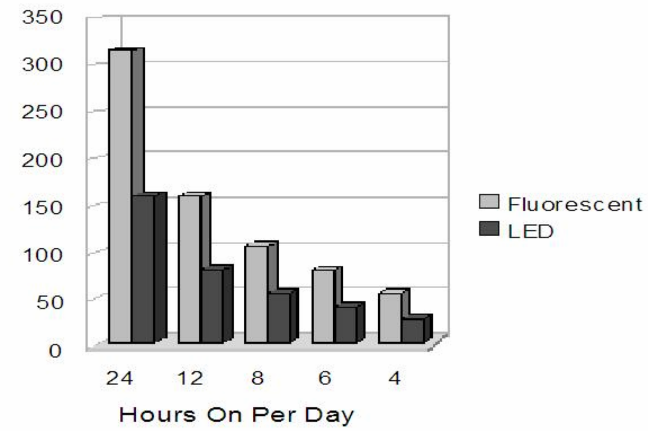


Fig. 7: Energy Consumption of Lighting Sources

V. CONCLUSION

LED technology improves rapidly from time to time but the devices are still too expensive to have a favorable total cost of ownership. However, this scenario may just as fluorescent lamps that have tremendous energy saving over a few decades ago, and LED lighting sources have a great potential to offer substantial energy saving for general lighting including internal applications. With the continuous improvement of LED technologies, it will become better suited to wider applications, increase the efficacies and qualities, and the price will fall. Therefore, the continuously research in improving the LEDs lighting sources are needed to achieve the global energy saving goals.

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