LEDs – A disruptive technology?

Light Emitting Diodes or LEDs have been heavily featured in the entertainment industry news recently, there's the law suit between Color Kinetics and Supervision of course, but there's also a proliferation of new fixtures appearing, particularly in Europe. Everyone is getting excited. But LEDs have been around as light sources for over 40 years so why are they suddenly attracting so much interest?

First fundamentally new successful lamp technology in 100 years

To answer that question we need to briefly look at their history. You could describe LEDs as the only fundamentally new lamp technology to enjoy commercial success in the last 100 years. Incandescent lamps have been around since the 1830's with the defining commercial moment in many people's mind being Edison's Menlo Park patent[1] of 1880. Arc lamps are even older, dating back to the early 1800's. You might have thought that fluorescent lamps are a modern invention, but not so; although they weren't commercialized until the 1950's the fundamental principles behind their operation were known in the 1860's when Becquerel demonstrated them in Paris. The sulfur lamp of the 1990s was new – but so far the technology hasn't lived up to its expectations and they haven't yet been a commercial success.

LEDs made the transition from the laboratory to commercial products in the early 1960s. Those first devices were infra-red only – no visible light – but they quickly found commercial use in sensors and scientific instruments. Their history since then has been a climb up in frequency, from the invisible infra-red to the visible with red appearing in the late 1960's, green and yellow in the mid 1970's and blue in the 1990's. Most recently they've left the visible spectrum at the other end and ultra-violet (UV) LEDs are now available.

Those early red LED's quickly became ubiquitous as indicators – every electronic device quickly adopted them to replace incandescent lamps. LEDs were smaller, easier to control, more robust and looked cool. They were a perfect component for the consumer electronics industry that was experiencing huge growth on the back of the recently invented transistor and the brand new integrated circuit.

That's where things stayed for a while – we got green, yellow and blue indicators as well as red and those indicators got steadily brighter. Today those indicators are everywhere – it's projected that every traffic light will be LED based by the end of 2005 and auto manufacturers are rapidly switching to their use in tail lights. Don't forget LED video screens - it's getting hard to remember what Las Vegas looked like before LEDs!

Indication not Illumination

However all these applications are for indicators where you look directly at the light source, not for illumination where the light source shines onto an object. To do that you need a much brighter source. Well, at the same time as LEDs were climbing the frequency spectrum they were also increasing in brightness. We have all heard of 'Moore's law' which predicts that the number of transistors you can cram onto an integrated circuit will double every 2 years. LEDs have their own law, dubbed 'Haitz's Law' after Dr Roland Haitz who worked at HP/Agilent/Lumileds. From examining the historical data he showed that LEDs had been doubling in brightness every 18 months since they were first commercialized and that there seemed every expectation that this trend would continue. *(Figure 1)*

---

[1] *Interesting to note that Edison's Patent (# 223,898) not only discloses the electric lamp but also the coiled filament still used today.*

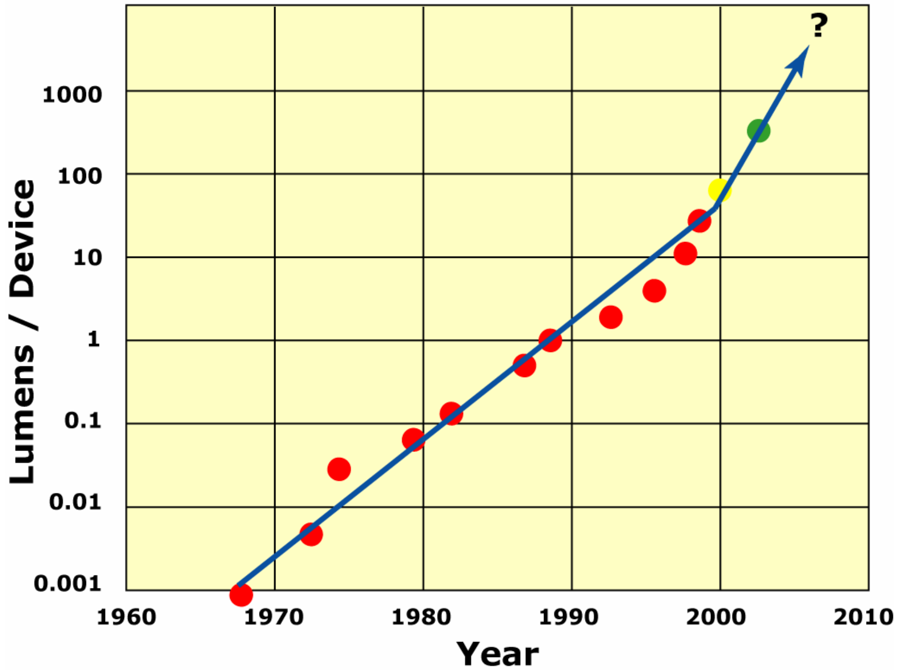

Figure 1 – Haitz's Law. Doubling in lumens per device very 18 – 24 months

Improvements over the last five years have meant that we have seen niche illumination applications open up. LEDs are now bright enough for museum lighting, accent lighting, outdoor path lighting and other low demand requirements. Of course the whole entertainment lighting industry is by definition a 'niche' market and we always love anything new – it's fundamental to our business – so we have become early adopters of the technology. However entertainment lighting is a tiny market compared to general lighting so, although our uses are exciting, it's not the real goal. We are just a spin-off application I'm afraid.

Brightness isn't everything

We talked above about Haitz's law and brightness, but just as important as the light output of a device is its efficiency – it's no good getting the light output you need if it takes you more energy to do it. For commercial lighting the targets are the incandescent and fluorescent lamps; the current workhorses of the lamp industry. If you can replace those with more efficient light sources then you can achieve true energy savings, something governments are rightly very enthusiastic about. So enthusiastic in fact that in 2002 the US Government passed legislation, the 'Next Generation Lighting Initiative', supporting research into these technologies. At that time the Department of Energy working with the OIDA (Optoelectronics Industry Development Association) established the following goals (Figure 2) :-

	LED 2002	LED 2007	LED 2012	LED 2020	*Incandescent*	*Fluorescent*
Efficiency, Lm/W	25	75	150	200	16	85
Lifetime, hr	20,000	>20,000	>100,000	>100,000	1,000	10,000
Flux, lm/lamp	25	200	1,000	1,500	1,200	3,400
Input Power, W/lamp	1	2.7	6.7	7.5	75	40
Lumen Cost, $ / 1000 lm	200	20	<5	<2	0.4	1.5
Lamp Cost, $	5	4	<5	<3	0.5	5
Color Rendering Index (CRI)	75	80	>80	>80	95	75
Markets Penetrated	Niche	Incandescent	Fluorescent	All		

Figure 2: LED lamp targets [2]

So far we are pretty much following this path (Figure 3), current commonly available LEDs have overtaken incandescent lamps for efficiency – but only just. That means they are achieving about 20 – 30 lumens/Watt. To put that figure in perspective an HID lamp (such as the familiar MSR or HMI) pushes the bar up to about 80 lumens/Watt and some current fluorescent lamps top the list at 100 lumens/Watt.

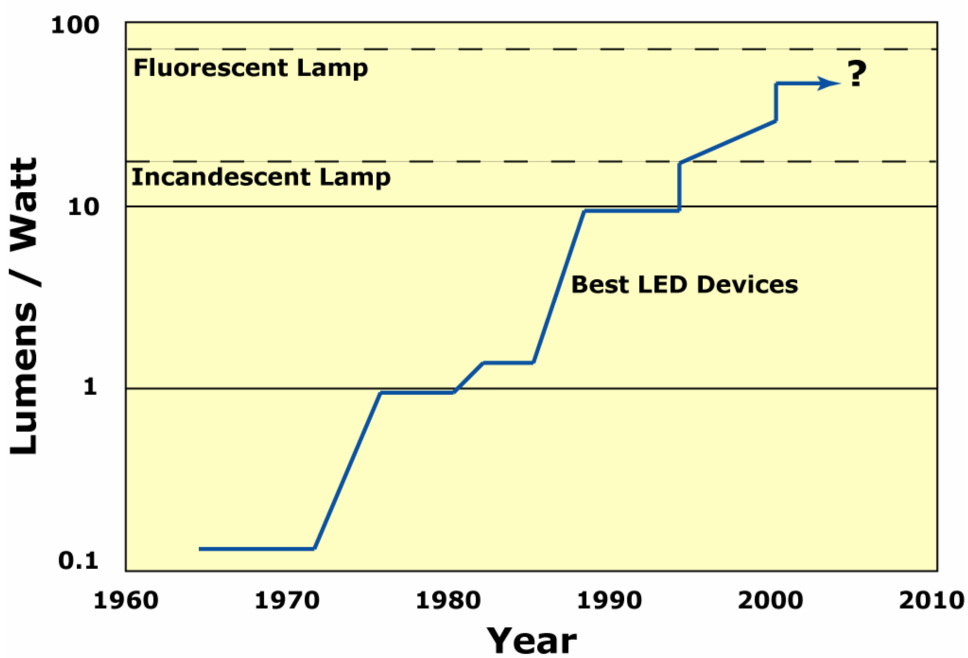

Figure 3 – LED efficiency. Every 10-15 years efficiency has gone up by 10x

[2] *OIDA, NEMA, Department of Energy Roadmap update – October 2002*

If these goals are achieved, and the government thinks they will be, commercial and domestic incandescent lamps will start to see serious competition in three years, fluorescents five years after that and world domination by 2020. You can see why the lamp manufacturers are taking notice. The benefits are obvious, not just in energy savings but also in reduction of mercury pollution (every fluorescent lamp contains mercury), savings in maintenance costs and extended lamp life.

So, why get excited?

At last we are coming close to answering the question at the top of this article, why are we getting excited right now? Well, three years is a very short time in product development – it really means you better be thinking about it today or you won’t be ready in time. In fact, two or three years before commercial acceptance is just about the time when the early adopters start to show niche products – and guess who’s an early adopter? The entertainment lighting industry, that’s who.

Of course all this is still a projection, not reality, and we shouldn’t take any of the developments needed to achieve these goals for granted. It’s going to need new discoveries, new technologies and new techniques to beat incandescent lamps never mind fluorescents. The humble MR16 lamp at $1 or so is really tough to beat!

Assuming that these high power, high efficiency LEDs can be produced there are still many problems to be solved. Our old public enemy #1 has still to be dealt with - **heat**. LEDs are very sensitive to overheating, not only does it significantly reduce their life and reduce their output, it also changes the color of the light emitted! They need a much cooler environment than an HID or a theatrical incandescent lamp will tolerate. That means more work and resource needs to be invested in cooling system design.

Getting the same color more than once

To make it even more complicated different color LEDs change output and color with both temperature and age but at different rates. Imagine the difficulty of designing a unit with Red, Green and Blue LEDs where you are trying to mix a specific color and make it match between fixtures. Firstly the three colors age at different rates - the blue might drop in output almost twice as quickly as the red so that at 10,000 hours that blue LED could be giving only 50% of the output it gave when new. Then they have different temperature dependency – they all shift towards longer wavelengths (i.e. get redder) as the temperature rises, but again, by different amounts. The combination is mind bogglingly confusing. The LED manufacturers are working hard to reduce these effects and the latest high-power devices are much more stable than previous generations, but these are still serious issues that need innovative solutions.

Tough problems, but none of them insurmountable with the ingenuity this industry is known for. I’m looking forward to seeing some of the off-the-wall solutions that I know are being developed.

We don’t want LEDs just because they are efficient of course; we want them because they have the potential of a stunning color range with dramatic and instantaneous color strobes; we want them because they give a cool, heat free, beam; we want them because they look good and perhaps most importantly we really, really want them because they are new and we thrive on novelty.

Mike Wood
Mike Wood Consulting LLC