INNOVATIONS IN LIGHT

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In association with John Gorse who presented at the conference

In this paper I hope to draw on some of the latest technological developments, new opportunities in the application of light and look towards the future. So what are the drivers of innovation? Lighting used to be a sleepy industry with innovations coming along every few years offering what at the time seemed significant benefits. These have mainly been driven by the need to improve energy efficiency and successive fuel crises around the world. The main focus was improving efficacy and since the first oil crisis in 1974 we have seen a range of innovative light sources launched on the market delivering more light for less energy with better colour. In the 80's we saw the introduction of electronics with HF ballasts, delivering more energy savings and a better quality of light to work under. Although difficult to quantify commercially these ballasts were shown to reduce incidences of headaches and eyestrain in workers. During this time there was extensive research into the benefits from light in reducing traffic accidents, reducing crime, improving our cities and increasing productivity. In 2002 we discovered the mechanism for controlling hormone levels in our bodies with light, opening up a new branch of research into the biological effects of light. This is now starting to feed itself through into practical applications. In the most recent years our attention has turned to global warming and how lighting can help to reduce our carbon emissions.

But come the new millennium the lighting industry has been going through nothing short of a revolution with the speed of innovation and change matching other high tech industries. The LED first appeared in 1963 as a practical electronic component, emitting low-intensity red light but by the early 90's modern versions were available with very high brightness's. These became a lighting curiosity but were of limited practical value as lighting tools. In 1994 Shuji Nakamura of Nichia demonstrated the first blue LED, an invention that was to place him alongside Swan and Edison in lighting history. The blue LED opened up the possibility of creating white light. This was first done by mixing the 3 primaries (red, blue, and green) and later by activating a phosphor plate in a similar way to a fluorescent tube. Major investment into high power LED light sources followed resulting in a year on year increase in efficacy that has outstripped any known light source to date. Currently the efficacy of LED's is increasing by 20% a year and this is expected to continue for a further 2-4 years. They are predicted to be 75% of lighting business by 2020, and by 2030 all our homes will be lit with LED's reducing the energy used in our homes by 90% compared to the tungsten lamp era. The efficacy of a LED is determined by 5 factors:

- Quantum Efficiency
- Electrical Efficiency
- Extraction Efficiency
- Phosphor Efficiency
- Package efficiency

and the practical limit is 220lm/w.

Some of the improvements in overall efficiency are due to the ability to control the light from such a small source reducing optical losses. The natural process of light emission within a LED produces light in a specific direction; hence they are very good where beams of light are needed. Whichever way you look at it LED's are set to dominate the lighting market in the future. For most applications there is now a LED solution that at the least will deliver a more energy efficient solution than conventional technology and as efficacy rises so cost/lumen will decrease.

The small size of the LED is creating new form factors for luminaires with size reducing and increased controllability. However we all have to learn the new language associated with these light sources and to understand that they operate by a different set of ruled to conventional lamps. The most common confusion is that the efficacy of the source is based on a junction temperature of 25^{o}C which is there for a fraction of a second before the junction starts to warm up. Of more use are the 'hot' lumens which is the output at operating temperatures. Luminaires have to be designed to keep the LED cool to maximise the output. So we see luminaires appearing with significant heat sinks. To help guide us through this minefield organisations like the SLL have produced guidance and the IEC is currently preparing performance standards. This is all a challenge for a traditionally slow industry which has been thrust into the semiconductor world and will bring new players into the lighting market.

Following close on the heels of the LED is the OLED, (Organic Light Emitting Diode) another solid state technology that will challenge conventional light sources and set to become a partner to the LED for the future. An **OLED** is a light-emitting diode in which the emissive electroluminescent layer is a film of organic compound which emits light in response to an electric current. They give a diffuse soft light rather than an intense beam. Table 1 shows the predicted performance improvement for OLED's over the next 5 years. The story will be similar to the LED with significant performance improvements year on year as the technology improves. However alongside this we will have new effects such as a transparent flexible OLED film that can transform itself into a panel of light.

Year	2012	2013	2015	2018
Efficiency	35 lm/W	60 lm/W	90 lm/W	130 lm/W
Intensity	3000cd/m²	3000cd/m²	5000cd/m²	5000cd/m²
CRI	>85	>90	>92	>95
Lumen Output	10,000 lm/m²	10,000 lm/m²	15,000 lm/m²	15,000 lm/m²
LT70@3,000cd/m²	10,000h	15,000h	20,000h	40,000h

Table 1

Applications for OLED will be for areas where general lighting is required (compared to accent lighting) such as shops, offices etc. And with the introduction of flexible films it is possible to imagine a whole range of architectural applications for this new light source.

We have had plenty of historic data on the benefit lighting controls can bring. The ability to simply switch off when lighting isn't needed, or dim down, or use a range of settings to create different moods within the same environment. Traditional control methods have required a control signal hard wired to a device and many of our light sources have limited ability to be controlled. Installing controls can save an additional 40% on the energy for interior applications and 60% for exterior. That doesn't mean turning lights off but controlling them to meet the need when there is adequate daylight or when the roads become quiet. Lighting controls also offer the possibility of changing the designed appearance by altering colour, direction and intensity. In commerce we have been used to installing lighting controls, although there is some scepticism as to whether they are used effectively. As we gradually switch over to LED lighting so the world of controls opens up. Switching is instant, dimming possible and we have the added option of colour change at our fingertips. (Although the author deprecates the use of gratuitous colour changing in lighting design!)

In our homes something more than the humble dimmer is largely unknown, and installing lighting controls in domestic premises, unless you are starting from scratch is an installation nightmare. However like most things these days it can now be solved by an 'App'. Lamps that contain their own IP address and link into a broadband router can be controlled from anywhere and at any time. Up to 50 lamps individually controlled in one system. Variations in colour and intensity are available without any additional wiring offering the most sophisticated scene setting for minimal cost. So as fast as we are installing wired controlled solutions so we must prepare for the wireless.

This new technology is enabling innovation in the application of light. At the same time as the LED was making an appearance we discovered the mechanism by which the body reacts to light and how it affects our physiology. Ten years later we are using this knowledge to build lighting installations that understand how we react to light and can improve our health and well-being.

In hospitals light and colour can be used to aid in the recovery from illnesses. Just some of the evidence linking the beneficial health effects of light can be seen in medical research and now we can build on this by designing lighting schemes that matches the patient's needs. This represents a step change in our approach to lighting design.

- Design & Health Scientific Review *"In fact, by installing brighter lights on a psychiatric ward, depressed patients had a three-day shorter duration of hospitalisation"*
- Psychosomatic Medicine *"Patients getting more sunlight experience less stress & lower analgesic medication use"*
- Journal of the Royal Society of Medicine *"After myocardial infarction: higher mortality in dull vs. sunny rooms"*
- Journal of Affective Disorders "*Bipolar depression: morning sunlight reduces length of hospitalization"*
- Infant Behavior and Development *"Neonatal ICs: cycled lighting improves pre-term sleep & weight gain*

In schools the effects of lighting can be used as an aid to concentration or act as a calming influence after a period of activity.

- University clinical centre for child and youth psychosomatic research , Hamburg
  - Concentration improves: 45% less errors made
  - Reading speed increases: 35% more words read
  - Restlessness decreases with 77%

Research has yet to single out the effect of lighting in academic attainment, but it has been shown to assist teachers in their daily work.

As we understand more about the physical effect of light so we will be able to move our design skills to enable seeing, to improving well-being in our work and rest.

Finally we can see how lighting is helping us enjoy our playtime. The summer of 2012 gave us the opportunity to showcase London to the world. In total 3.7 Billion viewers round the world watched over 100,000h of broadcasting from the London Olympics. The quality of the TV picture was critical and to a large extent relied on the lighting. High Definition and 3D television required lighting levels of 2000lux (towards the camera) while glare towards cameras and athletes had to be eliminated. However the use of Super Slow motion for replays created a new challenge. Camera shutter speeds were set at 300 frames per second, over 4x that used in Beijing. This higher shutter speed reacted with the natural 100Hz flicker from the discharge lamps to produce flickering image on super slow motion recordings. To counter this, electronic ballasts were developed to run at 250Hz square wave and produce constant light output with a flicker of less than 2%. Although this is a technique used in studio production it was the first time it had been used for the large scale broadcasting of sports events. The ballasts had to be developed to work with a standard floodlighting lamp and tuned to give optimum performance. For the broadcasters the solution was deployed in the Velodrome and over the diving pool. Both areas where there is fast action and where slowing down the action can produce dramatic television pictures. The result was perfect SSM pictures from every camera position. The Olympic Games produced a learning legacy in many areas. For lighting it is the endorsement of flicker free lighting which has now been taken up by many of the major football leagues as well as those planning new venues for upcoming sporting events worldwide.

The future is always hard to predict but with some degree of certainty we will see lighting becoming more respected as an exciting, innovative profession that can deliver energy savings improve our lives

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