The Debate that the IES felt they needed to delete from their Fires Forum

Author's note: For brevity, this like the deleted IES forum discussion does not include references. A fully referenced review appears in the March 2019 issue of Melatonin Research co-authored with Prof. Reiter. The author's company, Silas has been focused on quantifying the impact of photons on the human body and developing artificial environments that promote long term health by mimicking the entire solar spectrum. The author would like to thank the Edison Report for providing an open forum for this work.

Kids should be more important than Livestock

As the recent acquisition of Once by Signify illustrates, we know that the spectrum of lighting can improve not only the physical health but also the behavior of livestock. For the farmer, lighting has become an investment in healthier or at least more profitable livestock not just an energy savings because the impact on his bottom line can be quantified. Unlike caged livestock it is much more difficult to run controlled studies on humans, especially kids and we care about more than just bigger thighs. Seoul Semiconductor has shown that just 40nm more spectral content improves mood, EEG, and sleep patterns after just 49 hours of exposure. Over 4000 peer reviewed medical papers have been published showing that Near infrared (NIR) is used by the body to stimulate blood flow, repair cell damage, and increase ATP production at the cellular level. All these processes are at play in humans we just lack the rigorous research needed to quantify the effect. We do know that after millions of years the human body has developed more than a dozen bio-optical mechanisms beyond just circadian that take advantage of the entire solar spectrum not just the tiny slice we see with our eyes. These same bio-optical mechanisms are influencing our health in homes, offices, and schools for decades not just months defining sleep patterns, generating sickness, and molding the behavior/cognitive skills of children/elderly. Yet we are converting our schools, nursing homes, and prisons into modern day caves via misguided LEEDs standards and a false assumption that only visible light matters.

We need to Quantify the Problem Correctly

If the lighting industry wishes to transform itself into a health and wellness industry it will have to abandon the crude 2 dimensional empirical models used to date. Silas has shown that it is possible to generate 3D mechanistic bio-optical models of eye, skin, brain, and fetus by combining optical ray tracing from the lighting industry with Electron Spin Resonance (ESR) data from the health and beauty industry. This allows us for the first time to quantify how photons interact with our cells and compare the number of free radicals generated in 3D for any light source, any body type, and any time scale. Three common sources are shown in Figure 1 each emitting the same total number of photons every second.

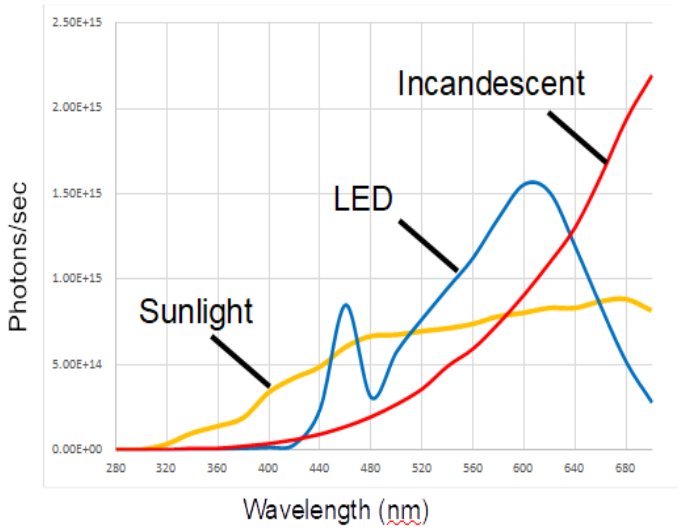

Figure 1

Based on ESR data we can predict the number of free radicals generated by each source as a function of wavelength in a given body type.

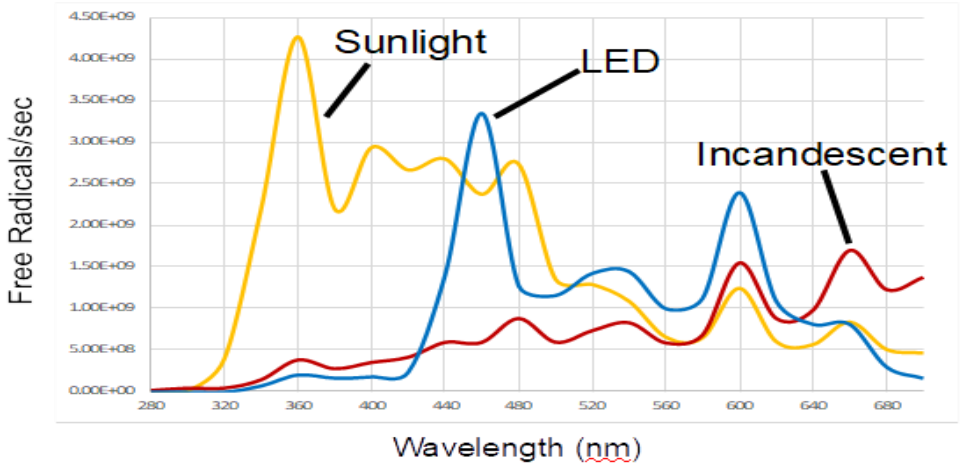

Figure 2

The optical properties of the tissue being exposed can be used to model via ray tracing where and what type free radicals are generated based on age, health, gender, skin color, etc. If the half-life of the free radicals is taken into account it becomes possible to study temporal effects like flicker/PWM as well. *Note: this simple example clearly shows that it is not just the blue photons that are generating higher numbers of free radicals, calling into question the benefit of blue blocking approaches.* In general, converting to photons/second is required to legitimately study any photobiological system and should be used as a guide to the validity of any research.

Unfortunately, virtually all lighting research to date has been empirical and 2 dimensional in nature and failed to take into account how photons interact within the various parts of the body, let alone how each of us are optically different. This has resulted in lighting being optimized for young white males, while discriminating against children, women, elderly, and certain ethnic groups.

Once the 3D free radical distribution is known it becomes possible to understand the underlying bio-optical mechanisms at play. To a first order, cellular damage is proportional to free radical density. Not surprisingly, the phototoxic action spectrum (pig's eyes) used by the lighting industry correlates very well with ESR action spectra (human skin) used in Silas models (corrected for lens transmission) as shown in Figure 3.

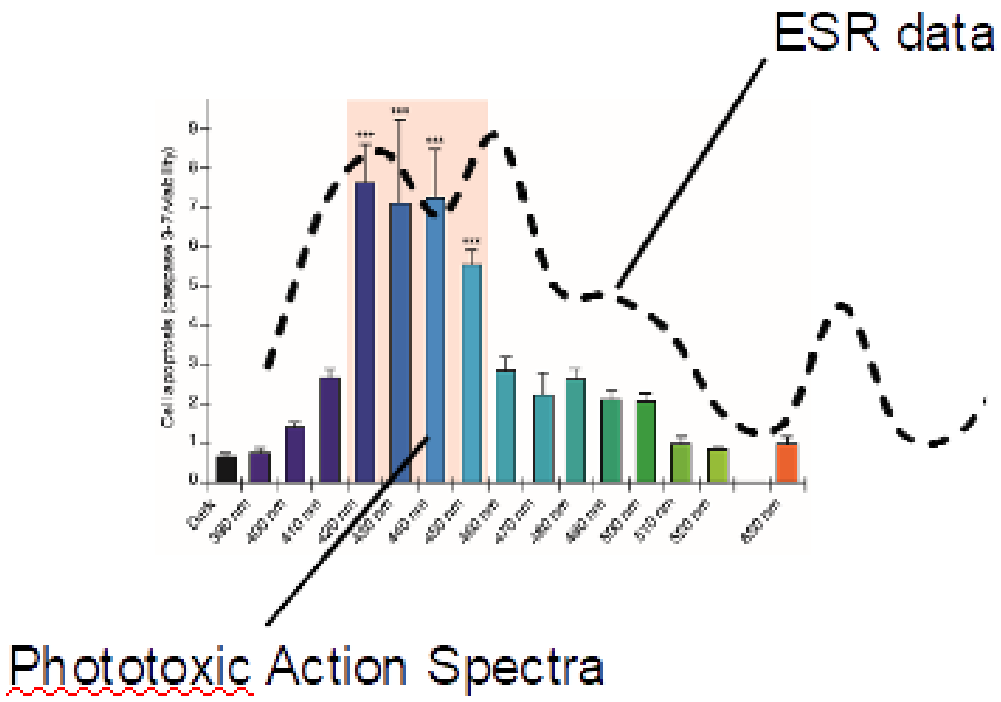

Figure 3

Another problem with 2D empirical approaches is that it makes it virtually impossible to compare results from one paper to another. In many cases, not even the Spectral Power Distribution (SPD) has been provided, relying instead on crude approximations such as color temperature, lux, or mW/cm2. Understanding how various wavelengths propagate in the human body explains why there has been so much confusion and contradictions in lighting research. Taking the next steps of free radical generation and antioxidant response opens up whole new avenues of discovery.

We need to recognize that the body uses the entire solar spectrum not just the tiny slice we see with our eyes.

LRC, IES, CIE have limited their research to visible photons passing through the pupil, which represents less than 10% of the spectrum we are exposed to in nature. While CIE may claim that Visible extends out to 815nm, we provide the public with 440nm to 640nm (200nm spectral content) making their argument mute. To understand the health impact of lighting/displays, the other 2000nm needs to be considered. The underlying assumption in lighting for the last century

has been that only visible photons entering through our pupil matter and that body type doesn't matter. These false assumptions ignore several key facts:

1. We are never exposed in nature to UV/Visible photons without an excess of Near Infrared (NIR) photons in a manner that is coincident and proportional to UV/Visible exposure levels.
2. In nature, we are exposed during the day to predominately NIR photons which interact with over 60% of our cells in adults and almost 100% of children's cells, stimulating antioxidant response and blood flow.
3. ESR data supports that virtually all wavelengths emitted by the Sun are generating free radicals and therefore are photobiologically impacting our cells even if we don't understand the exact mechanism or chromophore.
4. The majority of photons impinging on the retina don't come through the pupil.
5. The majority of melanopsin is in the skin and brain not the retina.
6. Deep red/NIR generates higher Melatonin levels at night.
7. NIR stimulates ATP production, blood flow, and antioxidant response.
8. 4000 peer reviewed medical journal articles are showing that NIR impacts dementia, AMG, cancers, myopia, etc.
9. A 2x difference in average annual solar exposure compelled the body to generate a 10x difference in melanin concentration.

By not taking the entire solar spectrum into account we have created an artificial environment which in many ways is exactly the opposite of what our body has been exposed to for millions of years. The USGBC and its LEEDs standard by mandating visible only LED lighting and requiring windows have NIR blocking coatings has created modern day NIR caves in our schools, offices, and homes. This is exactly the opposite of what we are exposed to in nature and a fundamental flaw in USGBC and NRDC motivations. The function of NIR is to repair and replace damage done by UV/HEV photons. Without NIR we are generating higher levels of oxidative stress in our cells. Over years this imbalance can lead to permanent cellular damage and its associated degenerative diseases. In many ways USGBC has mandated via LEEDs that we live in the most harmful artificial environment possible because of the narrow viewpoint and lack of scientific rigor in the lighting research community.

The human body assumes that we are exposed during the day to a single predominately NIR emitter, the Sun. That assumption is no longer valid. Even our surroundings (grass, soil, clouds, etc.) all absorb visible and reflect NIR, again exactly the opposite of what we do in our artificial environment. For the last 60 years, even if we worked under visible only fluorescent lighting, we came home in the evening to NIR rich incandescent lighting which increased melatonin levels and promoted better sleep. For 600,000 years before that, we gathered around a campfire each night exposing our cells to loads of NIR right before bedtime. Now we have eliminated NIR from our lives. We don't have a too much blue light problem we have lack of NIR problem.

We need to be honest with the public

The lighting community has not been honest with the public and the IES, LRC, Leducation, and trade magazines have ignored or actively suppressed debate in this area. One of the reasons for suppressing debate is that we are afraid of the public reaction. However, limiting debate and shrouding the facts under piles of scientific jargon is only creating legal liability for the industry. The goal was to save energy, but we need to be honest that there have been unintended consequences.

The incandescent bulb was constructed of glass and metal and had a Lumen/gram of raw materials over 30. We have replaced the incandescent bulb with a predominately plastic fixture containing a host of toxic materials ranging from lead to arsenic with a lumen/gram under 5 generating tons more trash. The plastics we now use instead of glass, emit toxic smoke, dropping the escape time from 30 minutes to less than 2 minutes in a fire and contributing to firefighters having one of the highest cancer rates of any profession. The lighting industry has become the major user of polycarbonate creating an entirely new waste stream of BPA (red listed material) to the environment.

We falsely label LED lights as being 3000K (only valid for blackbody emitters) when they only emit visible photons. We market LED filaments (zero NIR) as being just like incandescent filaments (90% NIR), creating probably the worse lighting source from a health standpoint ever created. From a photochemistry standpoint, clear envelope LED filament bulbs should be banned based on the

local damage done when the filament is imaged on the retina over and over again.

Pulse width modulation (PWM) and flicker found in lighting is directly modulating basic cellular functions. We know that free radicals are generated in the picosecond timeframe with the half-life of that free radical in the nanoseconds to several seconds range. The long-term consequences of modulating our cell functions is unknown but generally assumed to be negative.

We intentionally design lights to fail to cut costs, further increasing the probability that larger amounts of toxic and raw materials required in an LED light ends up in landfills. At this point it is reasonable to state that LED lighting is a net negative impact on the environment, especially if the added electronic waste is included.

Finally, mainly driven by brighter and more efficient light sources we are increasing light pollution reducing insect populations and pollination rates.

There are always unintended consequences.

We should not suppress debate because it is essential for discovery

The original work in this area is based on ESR data generated by the cosmetics industry to understand how to make a better sunscreen. The work even without the optical ray tracing models showed that the same number of free radicals are generated in our cells by Visible photons as UV photons in natural sunlight. This indicates that all wavelengths not just UV are photochemically active in the human body especially High Energy Visible (HEV). Adding in the optical model reveals that HEV photons are strongly absorbed near the basal cells at the epidermis/dermis junction. It has been known for decades that while UV blocking sunscreens prevent Squamous Cell Carcinomas (SCC) but they have almost no impact on Basal Cell Carcinoma (BCC) and in fact BCC rates have steadily increased for the last 30 years. What the 3D models show is why melanin deficient individuals get more BCC. UV only blocking sunscreens are effective at preventing sunburn (a natural warning signal) encouraging the public to spend more time in the Sun. This results in longer exposure to HEV photons leading to the increased risk of BCC. Melanin rich individuals have a very low risk of BCC in agreement with the hypothesis above except on their palms and bottom of their feet where melanin levels are lower and an associated increase in BCC in the black

population. The problem with this understanding is that introducing HEV absorbers to sunscreens and makeup is socially unacceptable (black face) and bad for marketing so further ESR research was terminated. BCC has a high recovery rate so the cosmetic industry appears to have decided to ignore the problem.

Amniotic and Cerebrospinal fluids both have peak transmission and minimal scatter in the NIR (850nm). The fetus and brain are surrounded by essentially clear optical fluids that in the NIR act just like the waveguides similar to what we use in lighting efficiently coupling NIR into every nook and cranny of the fetus and brain.

In the case of the fetus, the mothers skin filters out UV/Visible photons but passes NIR into what could be best described as fluid filled integrating sphere. As the pregnancy progresses, the fetus, until modern times was exposed to more and more spectrum as the skin stretches, an amazing optical design. We are now beginning to understand that NIR impacts fetal eye development and may even be linked to autism rates via the suppression of inflammatory proteins in the amniotic fluid.

The brain and skin contain more melanopsin and other photoreceptors than the retina. In the white fat cells of the skin melanopsin appears to trigger the release stores of beta carotene in proportion to sunlight exposure levels. In the brain, NIR exposures of less than 30 minutes have been shown to stimulate blood flow and reduce Alzheimer's symptoms. There is so much that could be discovered if the research groups would just look outside their silo and take a more rigorous approach to subject. This is a complex photochemistry problem involving biological systems not a lighting problem which is why the existing lighting research community appears to be struggling.

We need to accept the fact that we are in the discovery phase of how photons and human cells interact. This is why open debate is so important. Simply as an example of how discovery suppression occurs, Silas attempted to get the Bill Gates Alzheimers fund to look at the impact of visible only lighting/displays on dementia rates. ATP synthase in the mitochondria has been shown to be modulated into the Khz range by flashing lights. MIT has shown that 40 Hz pulsed light can decrease beta amyloid buildup in the brain. Ironically the very technology that allowed Mr. Gates to fund dementia research may be

contributing to higher dementia rates. The response was that they are looking for a drug to fund. That's not a criticism it is just an example of how discovery is so easily hindered by the status quo.

We need to be honest about when money not science is determining what we do. Example: Kids shouldn't have to take adult chemo drugs

Understanding the bio-optical mechanisms developed by the human body over millions of years could even help fight cancer. Yet less than 4% of the cancer research dollars go to kids and of that virtually all of it is based on drugs/protocols first developed for adults. Based on a well-intended philosophy and lower research dollars, kid's treatment options are limited compared to adults. The result being that if it isn't a drug it won't get funded. So, kids get adult chemo.

Optically children are much different than adults. Based on their size almost 100% of a child's cells "see" at least some part of the solar spectrum. This is easy to illustrate by comparing the light transmitted through a small child's hand versus an adult. What you see is a red glow that if you could see into the NIR would be about 10 times brighter. From ESR and over 4000 peer reviewed medical articles we know that the human body has developed a host of chromophores and bio-optical elements that take advantage of the non-visible portion of sunlight. We already know that light induced changes in melatonin levels dramatically impact cancer tumor growth rates. We also know from Tuchin's work that cancer cells absorb more than healthy cells at certain wavelengths in the NIR. Based on Silas models there appear to be narrow transmission windows at 1000nm, 1100nm, and 1270nm that could be used to enhance existing hyperthermia treatments that have already been shown in Europe to be effective against a host of cancers. But only limited research into non-drug techniques is allowed in the US based on big Pharma.

Conclusion

If the Lighting Industry intends on selling Healthy/Prescription Lighting we need to develop new methods of research, use different units of measure, and find people who can work with the medical community not fight with it. Foremost, we have a responsibility to "First do no Harm" as we replace sunlight and accept that we are presently doing harm to especially our children, elderly, and certain ethnic groups. Providing the right type and number of photons to our cells and

understanding what those photons are doing is a worthy endeavor. Suppressing research into these areas because it reveals problems with existing products not only is ethically wrong it stifles discovery. The lack of scientific curiosity is astounding as we literally are beginning to understand how the body uses sunlight to make us healthier, protect us against dementia/AMG/myopia, and maybe even fight cancer. The original Silas article was requested by the IES for the Fires Forum. After months of haggling the IES refused to publish the work and deleted all the posted comments from the forum which is their right. The real question is why? As one trade magazine editor stated "he needed to protect his readers". From what? Another architectural editor was honest enough to state that "it was not the message his advertisers were trying to convey". Edison understood that discovery is messy, contentious, and not always easy. Making it harder by suppressing debate and clinging to false assumptions because it might negatively impact existing products is not science.

Author – Scott Zimmerman has over 30 years and 85 issued patents in the lighting and display area.