Dr.Khan-generalized-letter-for-LEDlight-sensitive-individuals

Research · September 2021

DOI: 10.13140/RG.2.2.12296.55042

1 author:

M. Nisa Khan
IEM LED Lighting Technolgogies

[THE FOLLOWING LETTER USED A PSEUDONYM “Marie Johnson” TO PROTECT THE IDENTITY OF THE REAL PERSON WHO SUFFERS FROM LED LIGHTING. THE COUNTRY IS ALSO GENERIC – BUT THERE ARE MANY SUFFERERS OF LED LIGHTING FROM THE US, CANADA, UK, GERMANY, AUSTRALIA AND MANY OTHER COUNTRIES.]

September 7, 2021

To:
State Department of Human Rights
State, Country

Dear Madam/Sir:

I am writing this letter on behalf of Marie Johnson who is suffering epileptic seizures when exposed to LED lights. Light Emitting Diodes emit light from a flat chip, causing the cones of light to overlap which creates a spatial light distribution profile that overloads Marie’s central nervous system. The purpose of this letter is to explain why LEDs are not safe for lighting large living spaces.

Marie and many more like her who are light sensitive are debilitated when exposed to LED streetlights, LED vehicle lights and many other types of LED lights that unfortunately became ubiquitous in public places without government agencies conducting proper health studies and without the consent of the general public and residents in communities. Despite the fact that the lighting and optics industries have either misunderstood or purposely ignored the inconvenient mathematics and science of LEDs, LED lighting is increasingly replacing nearly all legacy lighting with the erroneous claim that they are more efficient compared to legacy lighting. LED streetlights do not save any appreciable amount of energy compared to modern high-pressure sodium and low-pressure sodium streetlights when recognizing that light from an LED is a directed-beam that produces very poor quality illumination [1]. The lighting produced by LEDs is poor because it produces too much light power in the middle of the lamp and along its center directional path while producing inadequate light power outside this narrow cone of directive light. The spectrum of LED lights is also unnatural causing further damage to our vision and general health.

I am an optics and lighting scientist as well as an engineer and a mathematician by training and I have worked in the field of optics, lighting and communication science and engineering for over 35 years. I was the first person to describe in a peer-reviewed scientific paper [2] how LED light distribution in space is entirely different compared to light generated from a spherical source. My reason for writing to you is to clarify why and how illumination from an LED-based lamp is of poor quality and why inorganic LEDs are not suited for large volumetric space illumination as required for streetlights and vehicle headlights.

While low-luminance LEDs are suitable for indicator lights such as exit signs and displays, this exact natural suitability for illuminating flat surfaces is the very reason why they are not appropriate for illuminating streets, warehouses, stadium arenas, and other spaces that are by nature volumetric regions that provide living spaces for us and other species. The very nature of illumination of these regions is that the viewers will invariably see the light source directly from certain regions and angles at times and this is unavoidable. This type of scenario is realized for drivers who cannot avoid looking at the lit LED car headlamps (high or low beam) from the drivers driving their vehicles in the opposite direction. The drivers who have to look at the lit LED car headlamps are then blinded or disoriented and this dangerous situation is now very common.

It is important to understand that public light sources will be encountered directly or indirectly by people going outside their homes due to necessities or for business and recreation. It is therefore imperative that we understand the fundamental differences in LED and laser light sources versus incandescent and gas-discharge light sources in their entirety and the devil happens to be, as expected, in the details.

Early lighting scientists realized that light providing us with illumination of our environment is fundamentally different from other light and general electromagnetic radiation used for applications such as radio communication and radar detection. The invention of the laser, which is coherent in nature, also allowed light to be used in applications such as fiber optics, welding, and medical surgeries.

Illumination science started with the sun providing daylight and the candle providing lighting at night. Pioneers of lighting science such as Johann Heinrich Lambert and Carl Friedrich Gauss correctly realized that illumination must be generated from an isotropic radiation source such as a point source to obtain a stable lit environment to properly view an illuminated object with stable color properties. The large distance between the earth and the sun allows us to receive stable illumination from the sun that, from our viewpoint, essentially acts like a point radiation source. A simple candle, while not a perfect point source, is nevertheless a substantially isotropic source in that it spreads light substantially uniformly for all of our viewing directions. This is illustrated in Figure 1 where the yellow region of the candle has a high degree of spherical uniformity, thus spreading uniform illumination over a large range of solid angles.

Figure 1 – Substantially uniform Illumination from a candle shown in the yellow region of the flame.

On the other hand, an inorganic LED is substantially flat and, by design, has a relatively small area to achieve very high quantum efficiency, meaning that it is highly efficient in converting electric power to radiant optical power. However, this energy efficiency characteristic of such a single LED chip is not translated very well to overall system lighting efficiency or lighting efficacy that is to be used for illumination purposes. Because such an inorganic LED in its chip form is typically only 1mm X 1mm, many such chips are needed to create a large enough LED lamp to achieve a similar total light flux or lumen power of the isotropic lamp it is meant to replace [3]. Inorganic LEDs are not point sources; and do not even slightly resemble a point source of light at any distance because LEDs are Lambertian light sources which are by definition **only** flat light sources. The requirements for quality, uniform illumination are now grossly violated by LED lamps due to the non-uniform luminance of LED chips and due to the nature of light aggregation of individual LED chips on flat boards. **Luminance is the technical lighting term for brightness, which is an inherent property of a light source.**

So what then is the problem with Lambertian light sources being used for illumination of volumetric space? Flat-surfaced radiation source is called a Lambertian source, after Lambert's useful work on defining flat-source radiation [4].

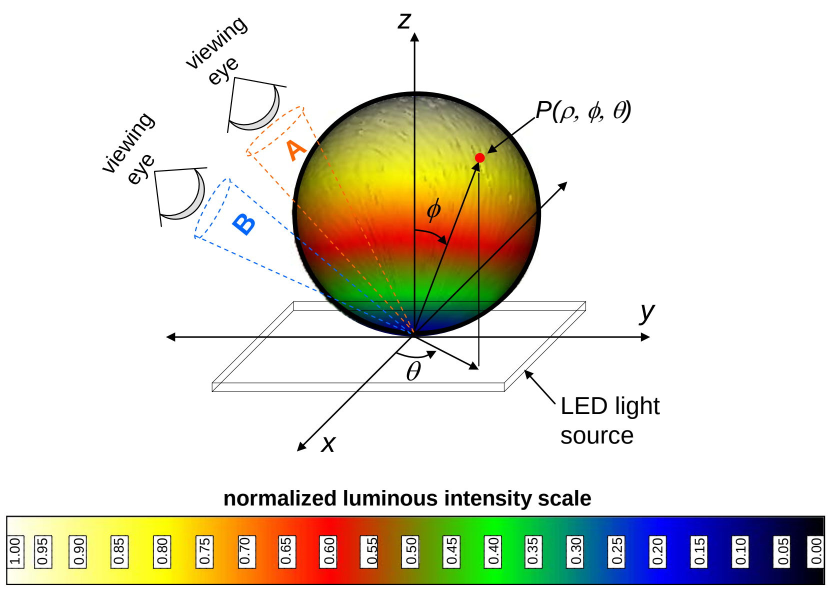

Figure 2 – Measured luminous intensity distribution (LID) data from a flat LED source showing the Lambertian light intensity distribution in 3D space [4]. Viewing from different angles shows substantially different luminous intensity quantities A and B in contrast to the case in Figure 1. Luminous intensity quantities are determined by summing the light densities within the cones.

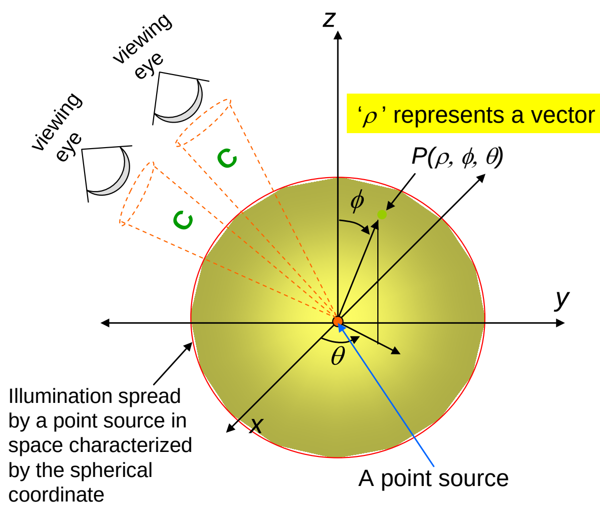

Figure 3 – A point light source placed at the center of the spherical coordinate system showing a uniform illumination zone all around the point source. Viewing from different angles shows the same luminous intensity, C, in contrast to the case in Figure 2.

Figure 2 is a Lambertian light intensity distribution (LID) generated from **only** flat light sources, whereas Figure 3 is the light intensity distribution (LID) generated **only** from a point source. In the two figures, the color difference and color variation difference relating to the intensity magnitude variation in space shows the real distinction between a Lambertian-source and a point-source emitter. The false colors are used to show the variations in light intensity magnitude from the two light sources. While Figure 2 represents LID from an LED or any flat light source, it also shows that the luminance distribution mapped in 3D space from a flat LED is also a Lambertian because luminance is luminous intensity per unit area. The only difference between a graph of luminous intensity distribution and a graph of luminance distribution is that luminous intensity is represented with an arbitrary spherical coordinate parameter ρ and therefore is arbitrary and unbounded, and quantified in lumen per steradian (an unbounded quantity); whereas for luminance, ρ has a fixed numerical value that provides the specific bounded quantity for luminance, which is measured in lumen per steradian per meter-squared [4].

The LED chip industry is similar to the semiconductor laser chip industry, which has measured the surface radiant intensity distribution from billions of LED chips and lasers in the last 40 years. The data unequivocally show that the light or radiant intensity distribution is similar to a Gaussian pattern on the chip surface, which clearly demonstrates that the light intensity over the surface of a flat source does not have a constant, uniform value. (The surface intensity distribution is nothing but the 2D projection of the luminance distribution that can only be graphed in 3D and conversely, one can map the 2D surface intensity distribution into 3D and obtain the luminance distribution.) In my peer-reviewed paper published by the Institute for Electrical and Electronics Engineers, I show that that whenever a Gaussian-like intensity distribution is obtained on a surface of a light source, then a Lambertian intensity distribution shall be generated from that light source in 3D space, and vice-versa. This mathematical relation can **only** occur for a flat light source. A substantially curved light source, spherical or not, will **never** generate a Lambertian LID in 3D space. Conversely, no Gaussian-like intensity profile will be generated on the surface of a curved light source.

In contrast to a Lambertian light source which is always a flat source, a theoretical point source of light is an infinitesimally small sphere. A practical point source of light is a finite-size source that is substantially spherical in shape, thus generating a substantially uniform luminous intensity distribution in 3D space as shown in Figure 3. What this means is that both luminous intensity and luminance from such a source is substantially uniform and constant at any viewing angle in 3D space. On the surface of such a light source, the intensity everywhere is substantially the same, and generally a constant quantity. An example of a practical point source is an incandescent light, which provides a substantially uniform light intensity distribution over a very large range of viewing angles in 3D space as seen in Figure 4 [5]. This is in stark contrast in relation to the Lambertian light distribution shown in Figure 2 where the light intensity quantities are substantially different at various viewing angles that fall within very small ranges.

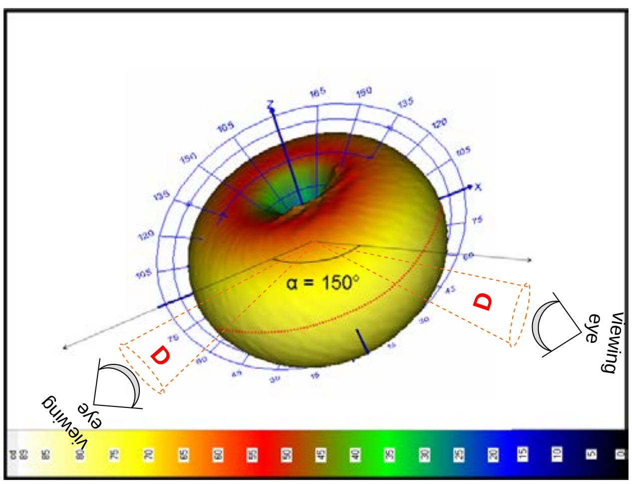

Figure 4 – Measured luminous intensity distribution (LID) Data from an incandescent lamp showing a substantially uniform light intensity distribution in 3D space [5]. Viewing from different angles shows substantially the same luminous intensity quantity, D, in contrast to the Lambertian case in Figure 2.

Our human experiences with sunlight, candles and fires, all of which have substantially **uniform luminance over very large range of viewing angles**, shaped the evolution of our vision system, sensory glands, and physical health over millennia. It is also the level of light intensity that falls on our eyes and other parts of the body from these natural light sources that are comforting for us and other biological species. The level of light intensity falling on our eyes and other body parts depends on the light source's luminance value, the size and shape of the light source, and how far we are from that light source. For visual sensation, this also includes the many light sources that are within our cone of vision.

Whether or not we directly look at LED light sources, we are adversely affected by their very high light intensity levels along the center line of the light beams generated by them and their unnatural as well as substantially non-uniform light intensity pattern in space. Many light sensitive people are immediately bothered by the unnatural as well as intense light from outdoor LED lights, which only gets much worse over time. LED streetlights, LED car headlights, or any other outdoor LED lights – generate grossly exceeding light intensity levels along the lamp's center direction axis and it is unsafe to have our eyesight or body parts subjected to them over time. Further, the type of light generated by LED streetlights, floodlights and LED vehicle lights is fundamentally different in the light distribution profile in both space and time from the more natural light distribution generated from substantially more uniform-luminance sources such as candles, incandescent and gas-discharge. **This non-uniform and unnatural light distribution profile is the main reason why a light sensitive person like Marie is almost instantly debilitated when exposed to this type of light.**

Because LEDs are Lambertian light sources and not point sources, the light generated from flat LEDs, and other flat radiation sources like cell phone antennas, are directive and therefore inherently produce beams that propagate in a particular direction. This is in sharp contrast to how the sun, or a candle, or an incandescent lamp diffuses light substantially equally in many different directions simultaneously. Because of this directivity, we may see the entire non-uniform light profile within our cone of vision. Even when our eyes aren't perfectly aligned with the center optic axis of an LED lamp (also known as the directivity axis) our field of view (FOV) still contains a good portion of this directed beam and we end up viewing the non-uniform luminance profile of the LED lamp. **What this means is that our eyes see a multitude of luminance values all belonging to the non-uniform luminance profile within a Lambertian distribution simultaneously or nearly simultaneously.** This experience overloads the central nervous system for many human beings and other biological species because we have not biologically evolved with non-uniform luminance light sources. **Because the peak luminance value of an LED streetlight exceeds the maximum luminance of high pressure sodium lights by a factor of several hundreds or thousands, when we visually encounter such an exceedingly large peak luminance and the varying luminance quantities at the same time, our range of experiences include loss of vision, disability, disorientation, migraine, seizures, discomfort and post-traumatic stress disorder (PTSD).** Some acutely light-sensitive people like Marie experience these harmful effects even from half a mile away simply because the light distribution profile in space from LED lighting is vastly different from those generated by high pressure sodium and other substantially uniform luminance sources.

All photometrics and colorimetrics in the lighting industry are based on the fact that the light source used for illumination has a substantially uniform luminance and luminous intensity. Standards bodies such as the Illuminating Engineering Society and American Association of State Transportation Officials have attempted to allow the existing standards or **slightly modified existing standards still**

<u>based on spherical or point sources</u> to be used for LED lighting. But this cannot and must not be done. New standards must be written before even considering the hugely non-uniform properties of flat-source light to be used for any illumination applications. The document, Exhibit F [6], by the Rennselaer Polytechnic Institute Lighting Resource Center (LRC) fails to quantify the non-uniformity of LED lighting behaviors. The LRC's assessment of how LED flicker might cause problems for people with epilepsy is **invalid because all of their measurement and quantification of light properties in the study are based on treating LED lights as uniform-luminance light sources.**

LEDs for illumination have been routinely mischaracterized by the lighting industry because the industry only measures LED lighting behaviors using the previously established point-source based photometry and colorimetry. This invariably assigns only one luminance value to an LED lamp which is substantially smaller than its true peak luminance value. This is the reason that current measurement techniques substantially underestimate LED glare along its directive axis. This is also the reason why their assignment of such CCTs as 4000K and 2200K to LED streetlights and other LED lights is invalid. Further, the lighting industry fails to measure the full 3D LID of LEDs in near-field and therefore fails to determine the true LED light distribution profile in volumetric space at typical viewing distances. **The luminous intensity or radiant intensity distribution at *<u>any</u>* distance (including what is meant by far-field intensity distribution) from a Lambertian source must be determined only from its near-field intensity distribution because the intensity distribution on the flat source surface is non-uniform.** The lighting industry usually blames LED lighting problems on glare, or flicker, or high blue light content. By ignoring the non-uniform light profile of LEDs, such characterizations are invalid. Glare is directly proportional to luminance and it is the **peak luminance** that must be properly determined to quantify the severity of glare a viewer encounters in the worst case. Also, unlike uniform light sources, LED light is not stable over time, or space due to its non-uniform luminance distribution. The continuous light generation from an LED source overlaps the remaining light distribution in space from previous moments at different points in space. **All such abnormal light activity realized in an unnatural fashion with multitudes of non-uniform intensities, various shapes and forms in space will overwhelm light sensitive people.**

Sincerely,

Dr. M. Nisa Khan
Ph.D. in Electrical Engineering
(Dr. Khan's Bio attached)

References:

[1] Pittsburgh (Studies available upon request.)
[2] https://ieeexplore.ieee.org/abstract/document/8879542
[3] https://www.researchgate.net/publication/290195141_Understanding_LED_Illumination
[4] https://en.wikipedia.org/wiki/Lambert%27s_cosine_law
[5] https://ieeexplore.ieee.org/abstract/document/8879542
[6] https://www.osapublishing.org/ao/abstract.cfm?uri=ao-54-21-6566
[7] Exhibit F (Studies available upon request.)

Footnote: The term 'light' is used in this document instead of 'lamp' for simple communication purposes with general readers. More technical lighting terms like lamps and luminaires are duly used in all my technical publications.

M. Nisa Khan is the author of, "Understanding LED Illumination" (CRC Press, 2013) – a widely used university textbook around the world in the field of laser and LED engineering and solid-state lighting. She received the B.A. in physics and mathematics from Macalester College in 1986 and the M.S. and Ph.D. degrees in electrical engineering from the University of Minnesota, Minneapolis, in 1988 and 1992 respectively. During her studies, she worked as a research associate for 9 years at Honeywell Solid State Research Center in Bloomington, Minnesota. After completing her doctorate, she became a member of the technical staff at AT&T Bell Laboratories (now Nokia Bell Labs) in Holmdel, New Jersey, and spent most of her 6 years at the Photonics Research Laboratory at Bell Labs-Crawford Hill conducting pioneering work on 40-Gb/s optoelectronic and integrated photonic devices. Dr. Khan then worked on optical communication subsystems at several other companies, including her own venture-backed companies in New Jersey. In 2006, she started an independent research and engineering company, IEM LED Lighting Technologies, and has since been involved in innovation and technology development for making solid-state lighting more suitable for general lighting. She has written over 40 peer-reviewed research articles in IEEE, OSA, and AIP journals, presented numerous invited and contributed papers at OSA, IEEE, and APS conferences, notable international conferences in Europe and China, and has 10 U.S. granted patents as either first or sole author. Dr. Khan performed many feasibility field studies for LED display and signage industries and wrote over 50 LED column articles from 2007 to 2016 in *Signs of the Times* magazine, which has been serving the electric sign illumination industry since 1906. Dr. Khan's original scientific contributions can be found in ResearchGate.net that highlight her discovery of why semiconductor lasers, LEDs, and RF antennas produce directional beams and she is the first to derive the closed-form, analytic equation for near-field electromagnetic radiation distribution from finite, flat radiation sources. This derivation along with the theory of Fourier Optics prove that LEDs, lasers, and flat RF antennas and their arrays are NOT point radiation sources no matter how far the observer is from a flat radiation source. This discovery is very notable and she explains with her new theory why high-power and high-brightness LED-based lamps - used for example as car headlamps - have tremendous glare that propagate directly into viewers' eyes when their field of view substantially overlaps with the center optical axes of the headlight beams. Her discoveries have been validated by experiments and finite simulations many times over and stand as very important work that can help the auto headlamp industry upgrade their photometric standards for non-point sources that produce non-uniform luminance and radiance - and adopt appropriate measurement techniques. Such work can demonstrate that many current LED headlamps have too great a luminous intensity along the optical axes of both high and low beams and they violate the current automotive lighting standards by NHSTA in the United States, and by CIE in Europe. Similarly, her work can prove that current 4G and 5G wireless signals generate dangerous levels of electromagnetic radiation for cell phone users and for residents who live nearby antenna base stations.