Soft Lights Foundation

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BY EMAIL

Erik Soskin, Inspector General
US Department of Transportation, Office of Inspector General
1200 New Jersey Ave SE, 7th Floor
Washington, DC 20590
hotline@oig.dot.gov

Re: Ford Motor Company False Claims of LED Headlight Compliance with FMVSS-108

Dear Erik Soskin,

The Soft Lights Foundation asserts that Ford Motor Company has been falsely claiming that LED headlights on Ford vehicles comply with federal safety regulations, specifically FMVSS-108. NHTSA refuses to properly investigate this issue, stating only that automakers are required to self-certify. LED headlights emit directed energy visible radiation which is not accounted for in FMVSS-108. Therefore, Ford's use of LED headlights fails to comply with FMVSS-108 for three reasons: a) Ford did not comply with the Administrative Procedure Act and did not receive approval to use LED headlights, b) FMVSS-108 is not applicable to flat surface LED visible radiation, and c) the peak luminance of the LED chips that Ford uses emit at least 70,000,000 nits, which we will show far exceeds the 20,000 maximum allowed candelas in Table XIX of FMVSS-108.

The Soft Lights Foundation is requesting an investigation of Ford by an independent, outside body with expertise in the spatial characteristics of the flat surface visible radiation emitted by LEDs. Our case is presented in the following pages.

Sincerely,

Mark Baker

Mark Baker
President
Soft Lights Foundation
mbaker@softlights.org

Request for Investigation of Ford's LED Headlight Claims

I. Introduction

In 1966, Congress passed the National Traffic and Motor Vehicle Safety Act which led to the creation of the National Highway Traffic Safety Administration.[1] The Federal Motor Vehicle Safety Standards under Section 103 of the Act are codified as CFR Title 49, Subtitle B, Chapter V, Part 571.

FMVSS Standard 108; 'Lamps, reflective devices, and associated equipment'[2] was written in 1967 when the standard light source for vehicle headlights was a tungsten filament which is a curved surface source of steady-burning light. The FMVSS-108 standard has not been updated to address any comfort, health, or safety issues related to the use of Light Emitting Diodes, which are a flat surface source of digital blue wavelength light.

In response to Soft Lights Foundation petitions NHTSA-220815-006, NHTSA-220818-001, NHTSA-220919-008, NHTSA wrote, *"…the Agency acknowledges that LED light sources have different physical properties when compared to halogen, incandescent, or a high-intensity discharge light source…*", yet FMVSS-108 has not been updated to address any of the different physical properties of LEDs or to set restrictions on properties such as spatial non-uniformity, peak luminance, spectral power distribution, or square wave flicker.

NHTSA also wrote, "*Under NHTSA's self-certification system, the manufacturer is legally bound to ensure their vehicles meet all applicable FMVSSs, including FMVSS No. 108."* NHTSA, however, declines to investigate the Soft Lights Foundation assertion that Ford is falsely claiming that LED headlights comply with FMVSS-108 during their self-certification process. Thus, the Soft Lights Foundation is requesting that an investigation be conducted by the Department of Transportation, Office of Inspector General.

Ford's LED headlights do not comply with FMVSS-108 in several different ways. First, LEDs are an electronic product whose regulation is overseen by the Food and Drug Administration. Ford failed to comply with the Administrative Procedure Act of 1946 which required Ford to petition NHTSA and the FDA for authorization to use LED headlights. Second, Ford claims that their LED headlights comply with FMVSS-108, when in fact FMVSS-108 has never been updated to include metrics for flat surface LED light and is therefore inapplicable to LED headlights. Third, as part of their self-certification process, Ford falsely claims that the luminous intensity of their LED headlights does not exceed 20,000 candelas as per Table XIX in FMVSS-108. Since the LED chips that Ford uses emit a peak luminance of at least 70,000,000 candela per square meter, it is mathematically assured that Ford LED headlights exceed 20,000 candelas at the required measuring distance of 100 feet.

The evidence for these assertions is detailed in the following sections.

[1] https://www.govinfo.gov/content/pkg/STATUTE-80/pdf/STATUTE-80-Pg718.pdf
[2] https://www.govinfo.gov/content/pkg/CFR-2004-title49-vol5/xml/CFR-2004-title49-vol5-sec571-108.xml

II. Administrative Procedure Act

The Administrative Procedure Act of 1946 details the federal process for formulating, amending, or repealing a rule and is described in 49 CFR Part 552. NHTSA and the auto industry are well aware of this law and typically follow these procedures. For example, Toyota Motor Corporation petitioned NHTSA to authorize the use of Adaptive Driving Beam on March 29, 2013.[3] Toyota was assigned docket number NHTSA-2022-0013-0002. NHTSA did not just immediately issue an authorization for Toyota to use ADB in their vehicles. Instead, NHTSA performed studies to confirm the functionality and safety of ADB systems.[4] The studies showed that ADB does not work properly, but rather than deny the petition outright, NHTSA simply declined to act. In 2022, under pressure from external sources, NHTSA approved Toyota's petition to use ADB, despite the fact that no studies showed that ADB was safe and functional.[5]

The approval of ADB systems hinges on the use LED headlights. The ADB system turns pixels on and off using sensors and computers to determine if there is an approaching vehicle or pedestrian. As we can imagine, this is an extremely complex system and it should not be surprising that this system fails on hills, bumps, and curves, and that oncoming drivers are briefly blinded before the ADB system reacts. Underlying all of this is the fact that neither Toyota nor Ford petitioned NHTSA for authorization to use LED headlights.

In 1968, Congress passed the Radiation Control for Health and Safety Act which directed the Food and Drug Administration to regulate electronic products and the electromagnetic radiation emitted by those products, including visible light. The FDA issued Title 21, Part I, Subchapter J, Part 1040 in the Code of Federal Regulations which is titled Performance Standards for Light-Emitting Products. The FDA has issued 21 CFR Part 1040.10 Laser products., Part 1040.20 Sunlamp products and ultraviolet lamps intended for use in sunlamp products., and Part 1040.30 High-intensity mercury vapor discharge lamps. Missing from this list is 21 CFR Part 1040.40 LED products.

Because 21 CFR Part 1040 for LED products does not exist, Ford was required to submit a petition to the FDA to request the initiation of the regulatory process to set performance standards for LED products, just as Toyota did when petitioning NHTSA for authorization to use ADB. After receiving the petition from Ford, the FDA would have either rejected Ford's petition, or would have performed investigations to determine the necessary restrictions on spatial non-uniformity, peak luminance, spectral power distribution, and square wave flicker, all characteristics of LED flat surface sources that make LEDs different than tungsten filament sources. Because neither Toyota, nor Ford, nor any other entity has petitioned the FDA, the Soft Lights Foundation has filled the void and has submitted a petition to the FDA to regulate LED products, including LED vehicle headlights. The assigned document is FDA-2022-P-1151.[6]

In this section, we have proven that Ford has violated the Administrative Procedure Act and has no regulatory authorization to use LED vehicle headlights.

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[3] https://www.regulations.gov/document/NHTSA-2022-0013-0002

[4] https://www.nhtsa.gov/DOT/NHTSA/NVS/Public%20Meetings/SAE/2016/P135968%20SAE%20_Mazzae%20ADB.pdf

[5] https://www.nhtsa.gov/sites/nhtsa.gov/files/2022-02/ADB-Final-Rule-02-01-2022-web.pdf

[6] https://www.regulations.gov/document/FDA-2022-P-1151-0001

III. FMVSS-108 Inapplicable for Flat Surface LED Emitters

FMVSS-108 was written in 1968, in a decade when LEDs had just been invented. As we can imagine, the authors of FMVSS-108 likely did not consider a time when LEDs would be powerful enough to be used as a vehicle headlight. There are many built-in assumptions within FMVSS-108. For example, even though the word 'light' is used throughout the standard, the word 'light' is never defined. Instead, we must infer that 'light' means electromagnetic radiation in the human-visible portion of the spectrum, and that FMVSS-108 does not apply to microwave or radio frequency electromagnetic radiation. Similarly, after a thorough reading of the entire FMVSS-108 document, we can infer that FMVSS-108 is only applicable to curved surface emitters because there is no mention of characteristics such as spatial non-uniformity, peak luminance, spectral power distribution, or square wave flicker, all of which are inherent to flat surface LED emitters.

Given that FMVSS-108 is only applicable to electromagnetic radiation in the human visible portion of the spectrum and given that FMVSS-108 is only applicable to curved surface emitters, it is clear that Ford cannot claim that LED headlights comply with FMVSS-108. NHTSA, however, disagrees. In their December 2, 2022, response letter to the Soft Lights Foundation, NHTSA claims that FMVSS-108 is applicable all lights sources, regardless of surface geometry. However, as shown in the previous paragraph, this simply is not true. NHTSA's only justification to their claim is to say, "*A key to understanding this topic is that the integral beam photometry requirements are for the lamp, not the light source.*" This is a major error in understanding of physics by NHTSA. By ignoring the spatial shape of the light source, NHTSA has erred in its belief that flat surface LED light sources are just the same as any curved surface light source. The DOT-OIG's report titled Weaknesses in NHTSA's Training and Guidance Limit Its Ability To Set and Enforce Federal Motor Vehicle Safety Standards[7] from November 9, 2021, explains how this error likely occurred. NHTSA has no training or expertise in flat surface radiation devices such as LEDs. This explains why NHTSA has not updated FMVSS-108 to include restrictions for flat surface LED sources and why NHTSA has not understood the impacts of LED sources on intensity and glare.

NHTSA wrote in the December 2, 2022, letter to the Soft Lights Foundation, "*In consideration of the foregoing, NHTSA does not believe that a formal investigation is warranted, and NHTSA has decided to deny Soft Lights Foundation's petitions for non-compliance orders on the subject vehicles.*" The decision by NHTSA to not even open an investigation implies that NHTSA believes that FMVSS-108 is perfect as-written and needs no updating for flat surface LED vehicle headlights. The problem with NHTSA's decision to not even open an investigation is that NHTSA then fails to explain why LED headlights are creating dangerous and debilitating glare that puts the comfort, health, and safety of the public at risk.

A. Photo and Video Evidence

[7] https://www.oig.dot.gov/library-item/38698

Figure 1 is an example of tungsten filament headlights. Notice the yellowish color, the ability to see most of the vehicle, and the low contrast with the surrounding environment.

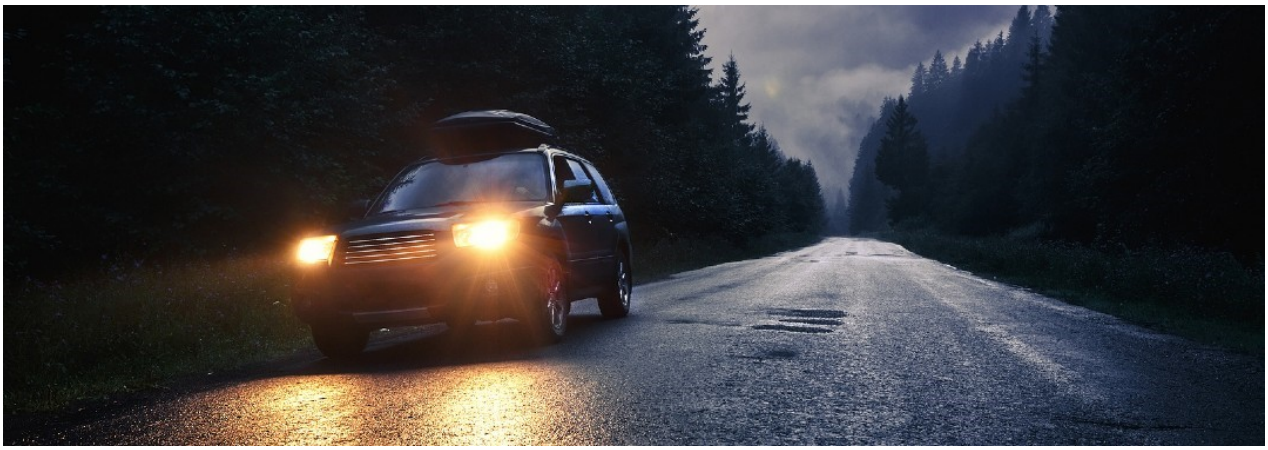


Figure 1 - Tungsten Filament Headlights[8]

In comparison, Figure 2 is an example of LED headlights. Notice the bluish color, the blinding glare that hides the entire vehicle, and the high contrast with surrounding darkness. Watch the full video: https://youtu.be/sQHpikG7UhA

Figure 2 - Glare from LED Headlights

[8] https://www.usautosales.info/blog/pros-and-cons-of-halogen-and-led-headlights/

In the December 2, 2022, response letter to the Soft Foundation, NHTSA states that they believe that LED headlights in Figure 2 comply with FMVSS-108. If FMVSS-108 allows such dangerous glare, then it is clear that something is wrong with FMVSS-108. As stated earlier, FMVSS-108 simply is not applicable to LED headlights, and Ford cannot claim that their LED headlights comply with FMVSS-108. Figure 3 is another example of LED headlight glare.

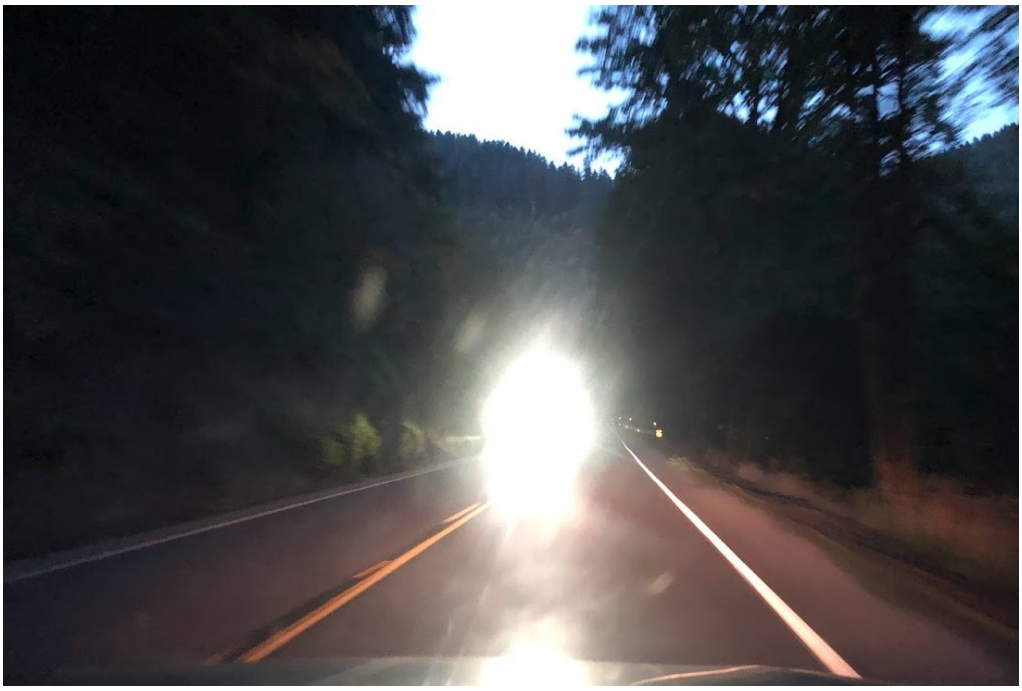


Figure 3 - LED Headlights

These videos show the blinding glare of LED headlights and resulting crashes or near-misses.

1. https://www.reddit.com/r/IdiotsInCars/comments/zbtt4k/i_couldnt_see_anything_except_bright_headlights/
2. https://external-preview.redd.it/MLCYAdoPptm_uSaKv2ZkGDzjnbM4-zfXukD95R5eKN4.gif?format=mp4&s=ff06a307bae58774ef0ecc5e23bcce9e95cdf702
3. https://www.reddit.com/r/fuckyourheadlights/

B. Public Complaints

The following are a tiny sample of the thousands of comments from the change.org petition that has nearly 35,000 signatures and comments demanding that NHTSA ban blinding LED headlights.[9]

[9] https://www.change.org/p/u-s-dot-ban-blinding-headlights-and-save-lives

Viviana Martinez
44 minutes ago

I can't see when there's a car with bright headlights behind me. There's no way to get away from the light and it's super dangerous to guess at where you're going when you're driving.

Liana Fan
1 day ago

It is terrifying to drive at night with these blinding lights. It is such a danger

Lori Connell
1 day ago

I almost cannot drive at night now- it's so disorienting. I can't concentrate on driving safely when oncoming lights hit me in the eye- I'm blinded. And the ones coming up from the rear give a triple blinding effect in rearview and side mounts all at once. It completely alters depth perception.

Makaila Carpenter
2 days ago

I have an astigmatism and these LED headlights make driving dangerous and nearly impossible.

linda kelly
3 days ago

Lights blind other drivers and cause deaths and accidents

Tina Dougherty
3 days ago

I totally agree with this petition. I done like driving at night for this reason! It is so dangerous for these lights to be used as headlights.

Ruth MacGabhann
3 days ago

These lights are blinding and make driving in the dark very difficult!

Vanessa Herrera
4 days ago

I have to pull over every time someone with led headlights comes towards me. If I look at their lights. I'm blinded for several minutes

wilmot Price
6 days ago

I have been blinded by these kinds of lights many times.

Louise Dell
1 week ago

I have been blinded far too many times by these lights and have had many near misses! In the dark they dazzle you, and then you can't see properly for minutes after

Christen Croft
3 weeks ago

I wholeheartedly agree. It's dangerous! When they are coming toward me in a narrow dark road at night, some headlights are so blinding and I have to hope for the best until the other vehicle passes. When they are directly behind me, I have to fold my rearview mirror up (which is dangerous in and of itself, but still less so than not doing it) so that I can see on front of me and that only helps so much, since the glare from them are still blinding me from my sideview mirror. I don't understand why this has been allowed to become such an issue, in the first place. I hope this will save some lives.

ryan hansmann
3 weeks ago

I am a professional driver and the harsh white light makes working dangerous and hard to see while driving at night.

Kenneth Moya
4 weeks ago

We're in Southern California where there's streetlights every 15 feet. You don't need these here, and we NEED to be able to see in front of us instead of using both hands to block the rear and side view mirrors when you're behind us.

Jenny Isadore
4 weeks ago

LED head lights are blinding and very dangerous. Especially at night in the rain when you can't see the lines on the road or anything in front of you because you're blinded by LED head lights.

Neither Ford nor NHTSA have addressed these complaints from the public. Since the public is clearly being harmed by LED headlights, and since Ford's LED headlights are creating harm, FMVSS-108

is clearly not applicable to LED headlights. Until FMVSS-108 is updated to include regulations for LED headlights, Ford cannot claim that their LED headlights comply with FMVSS-108 or that LED headlights comply with the Motor Vehicle Safety Act of 1966 which states: "'*Motor vehicle safety' means the performance of motor vehicles or motor vehicle equipment in such a manner that the public is protected against unreasonable risk of accidents occurring as a result of the design, construction or performance of motor vehicles and is also protected against unreasonable risk of death or injury to persons in the event accidents do occur, and includes nonoperational safety of such vehicles."* LED headlights create an unreasonable risk of accidents as a result of their design and the public is thus not protected against an unreasonable risk of death or injury.

C. Warning Labels

Shown below are the warning labels for several LED products, alerting the operator that LEDs can cause momentary blindness, eye damage, and vision loss, even at a distance. Ford uses similar LED devices in their car and truck headlights that are pointed directly or nearly directly into the eyes of babies, children, adults, the elderly, oncoming drivers, pedestrians, and wildlife.

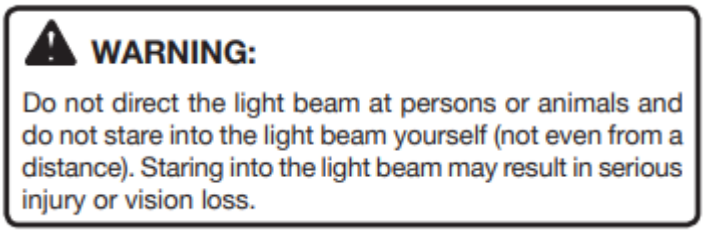


Figure 4 - Ryobi LED Warning

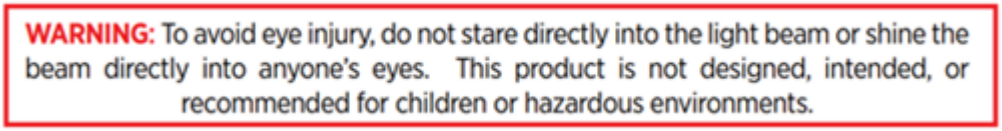


Figure 5 - GearLight LED Warning

Figure 6 - Whelen Engineering LED Warning[10]

[10] https://www.whelen.com/wp-content/uploads/2020/08/14555.pdf

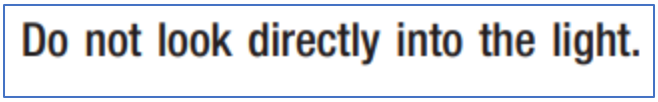


Figure 7 - Feit Electric LED Warning[11]

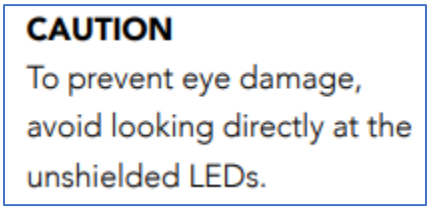


Figure 8 - Hydrobuilder LED Warning[12]

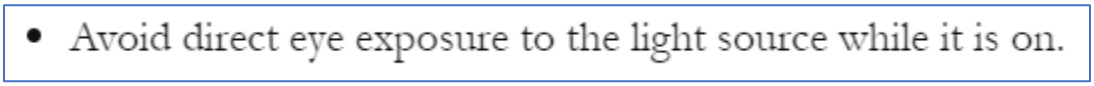


Figure 9 - Acuity Brands LED[13]

The Ford.com homepage has a video promoting Ford's switch to electric vehicles. The video prominently shows the Ford electric vehicle using these same LED lights that manufacturers of other LED products have placed labels on which warn about momentary blindless, eye damage, and vision loss, and warning users not to shine these lights directly into the eyes of a person. Yet, Ford's video clearly and prominently shows the LED headlights and C-shaped lightbar shining directly into the eyes of the viewer.

[11] https://www.feit.com/wp-content/uploads/2019/09/LEDR56FP_927_MANUAL.pdf
[12] https://hydrobuilder.com/media/pdf/instructions/ROI-E720-user-manual.pdf
[13] https://img.acuitybrands.com/public-assets/catalog/753016/epanl-instruction-sheet.pdf?abl_version=12%2f06%2f2021+12:23:30&DOC_Type=Installation_Instruction_Sheets

Figure 10 - 2022 Ford Electric Truck[14]

Figure 11 - Ford Electric Truck Closeup

Figure 12 shows Ford's 2021 Bronco using LED headlights. Ford's claim that these LED headlights comply with the letter and spirt of the Motor Vehicle Safety Act of 1966 cannot be justified. These LED headlights have extreme levels of high-glare blue wavelength light, create a visual distraction, and emit excessive luminance. It must also be noted that LED headlights will trigger epileptic seizures, debilitating migraines, anxiety, and loss of visual freedom, violating civil rights protections. Ford's failure to petition the FDA for approval and the necessary publication of comfort, health, and safety regulations for LED products has led this dangerous and discriminatory situation.

[14] Ford Homepage 2-26-2022 – www.ford.com

Figure 12 - 2021 Ford Bronco LED Headlamps[15]

IV. LED Headlights Do Not Meet FMVSS-108 Table XIX Requirements

Even if Ford is able to use NHTSA's position on FMVSS-108 as being applicable to LED headlights as legal cover, Ford will be unable to justify their false claims that LED headlights meet the FMVSS-108 Table XIX requirements of a maximum of 20,000 candela. Since FMVSS-108 is not designed for flat surface LED sources, it is convoluted to try and use FMVSS-108 for LED headlights. Yet, we can still show that, even if we use FMVSS-108 for LED headlights, the Ford LED headlights still fail to meet FMVSS-108 Table XIX requirements.

FMVSS-108 uses the metric luminous intensity, measured in candela. This metric essentially describes the number of candles as viewed through a solid angle (steradian). Because of the inverse square law for dispersion, a 20,000-candela curved surface source will appear brighter at 100 feet and less bright when viewed at 1 mile. The same solid angle would be used at the two different measurement distances, but because the same angle encompasses a larger volume of space at 1 mile than at 100 feet, the amount of light within the cone will be more dispersed and less dense.

However, a flat surface LED source creates a directed beam of spatially non-uniform energy within a tiny volume of space and there is very little dispersion by distance. This means that the light from an LED will be just about as intense at 100 feet as it is at 1 mile. FMVSS-108 is based on the fundamental concept that light emitted from a source will disperse following the inverse square law. However, **LED light does not disperse following the inverse square law**. The LED display industry correctly uses the metric 'luminance' measured in candela per square meter (nits) for flat surface

[15] https://motorillustrated.com/ford-bronco-grille-and-headlights-revealed-in-new-teasers/51219/

emitters. NHTSA FMVSS-108 does not mention the metric luminance at all, and thus Ford's claim that their LED headlights comply with FMVSS-108 requires significant contortions, and within all those contortions, it emerges that Ford's LED headlights exceed the 20,000-candela maximum specified in Table XIX of FMVSS-108.

Figure 13 is a table published by Hella, an LED chip vendor for Ford. It is fundamental to note that the table uses luminance, not luminous intensity. As of 2013, Hella's LED headlights had reached peak luminance of 70,000,000 candela/m^2, as shown in the table.

3 LED HEADLIGHTS ADVANTAGES: COMPARISON

LEDs are superior in several aspects. They might be more expensive to purchase than normal light bulbs or halogen bulbs, but their use pays for itself in a short time. The automotive industry in particular uses the positive features of the LED and employs it increasingly in new vehicles due to the following advantages:

Light Source	Luminous flux [lm]	Efficiency [lm/W]	Colour temperature [K]	Luminance [Mcd/m2]
Conventional bulb W5W	~ 50	~ 8	~ 2700	~ 5
Halogen bulb H7	~ 1100	~ 25	~ 3200	~ 30
Gas discharge D2S	~ 3200	~ 90	~ 4000	~ 90
LED 2.5 Watts	~ 120 (2010) ~ 175 (2013)	~ 50 (2010) ~ 70 (2013)	~ 6500	~ 45 (2010) ~ 70 (2013)

Figure 13 - Headlight Luminance[16]

Since **LED radiation does not disperse over distance**, then all 70,000,000 candelas will fall onto a 1 square meter surface at the 100-foot measurement distance. 70,000,000 candela/m^2 x 1 m^2 = 70,000,000 candela, exceeding the limit of 20,000 candela specified in FMVSS-108 Table XIX. This statement is the crux of the case against Ford. Ford's self-certification process is using measurement devices and techniques that were designed for curved surface emitters, not LEDs. Hella is correctly providing intensity measurements in luminance, which is how Ford should be measuring the intensity of their LED headlights. Ford's convoluted attempt to self-certify LED headlights using metrics and measurement devices not designed for LEDs leads to invalid results. Ford is then providing these invalid results to NHTSA and falsely claiming that LED headlights comply with FMVSS-108.

As confirmation that the preceding paragraph is accurate, consider this paragraph from Konica Minolta: "*For luminance measurement, the field of view (FOV) of the sensor must be smaller than the source. The FOV of a luminance meter is about 1◦ . The FOV of a digital camera pixel is on the order of 150 times smaller, so it can measure small area light sources such as individual light emitting diodes. These sources are* ***difficult or impossible to measure with a luminance meter***"[17] In fact, since LED chips emit spatially non-uniform energy from a very tiny flat surface source, the precision scale necessary to accurately measure the luminance is at the picometer or femtometer scale.

There are two ways to fix Ford's measurement problem. The first method would be to update FMVSS-108 to specify a maximum allowed chip-level peak luminance value which would be used instead of specifying a maximum candela at 100 feet. The second method would be for Ford to use the extremely precise measurement techniques that Hella uses and measure the peak luminance in near

[16] Hella - https://www.hella.com/techworld/us/Technical/Automotive-lighting/LED-headlights-833/
[17] https://www.atecorp.com/atecorp/media/pdfs/data-sheets/tektronix-j16_application.pdf

field (approximately 1 micrometer from the LED chip). By using imprecise measuring devices at 100 feet from the headlight as per NHTSA standards, Ford is invalidly averaging out the density of the LED light and failing to use the required femtometer or picometer precision.

Another item to refer to in the Hella table is the Color Temperature. As can be seen in the table, a conventional tungsten bulb is 2700 Kelvin, which means that it emits a low amount of toxic blue wavelength light. On the other hand, a Hella LED chip has a CCT of 6500 K, which means that it emits an extreme amount of toxic blue wavelength light and excessive dangerous glare. Again, Ford's failure to comply with the Administrative Procedure Act and failure to petition NHTSA for approval to use such a high CCT light source makes Ford's vehicles non-compliant with the Motor Vehicle Safety Act of 1966 because the inherently high-glare LED headlights are a huge safety issue, putting the public at high risk of injury or death. It should be noted that NHTSA's references to its 2007 Congressional report on glare does not include an investigation of the glare from tiny LED chips[18]. NHTSA's reliance on the 2007 report to show that the size of the source does not matter is invalid and in error and NHTSA's failure to specify a maximum level of blue wavelength light is endangering public safety and may be leading to permanent eye damage.

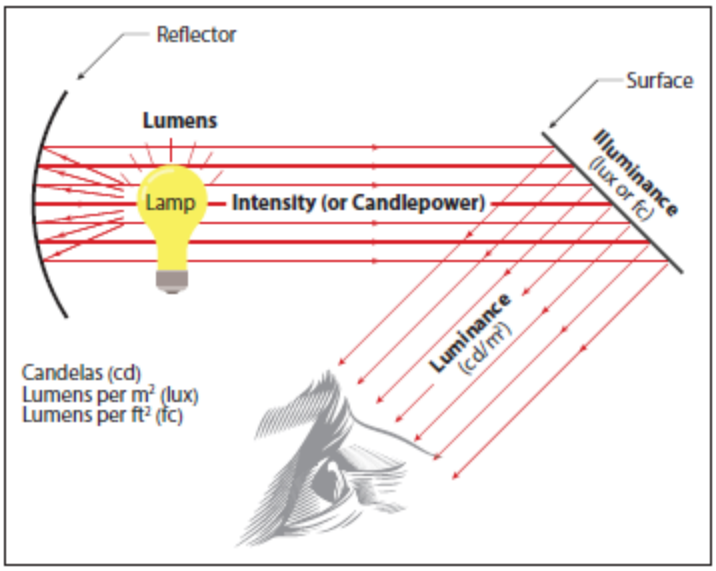
V. Curved vs. Flat Surface Emitter

The invention of a flat surface device that emits visible radiation has created a new class of light source that requires a different set of metrics from curved surface light sources.

Curved Surface Emitter

Figure 14 is a diagram of basic lighting terms from the Illuminating Engineering Society. As can be seen in the diagram, the lamp emits uniform energy in all spatial directions, eventually entering the eye with spatially uniform (isotropic) energy. The metrics for the light entering the eye from the flat surface is called luminance and is measured in candela per square meter, also known as nits.

[18] https://www.nhtsa.gov/sites/nhtsa.gov/files/glare_congressional_report.pdf



Relationship of basic lighting terms.

Figure 14

The brightness of the lamp is measured by the metric called luminous intensity, measured in candela. Because the energy emitted by the lamp is spatially uniform, the light will spread out following an inverse square law and will become less dense and less bright as the distance increases. Also, because of the uniform spatial energy, a single value can be used to measure the luminous intensity, and a single value can be used to measure the reflected luminance from a flat surface which was originally emitted by a curved surface. Mathematically, the light can be modeled as a single, infinitely small point and the light source can be considered a point source.

Flat Surface Emitter

The invention of solid-state lighting, which uses a flat surface chip to generate light, dramatically changes the properties of the light that's emitted. The photons emitted by the chip randomly escape at different angles, but because of the flat geometry of the chip, some of the light rays will overlap. The center of the chip is where the most overlap occurs, with the least amount of overlap occurring near the edges. There is almost no light emitted from behind the chip. These important differences are not considered with current metrics.

Figure 15 shows a flat surface as the source of the light. The overlapping light rays create spatially non-uniform (anisotropic) energy, as each point in space has a different amount of energy. The mathematical profile of light from a flat surface generally follows Lambert's Cosine Law, which describes the amount of energy at each point in space.[19]

[19] http://www.softlights.org/wp-content/uploads/2022/03/Lambertian-2013.pdf

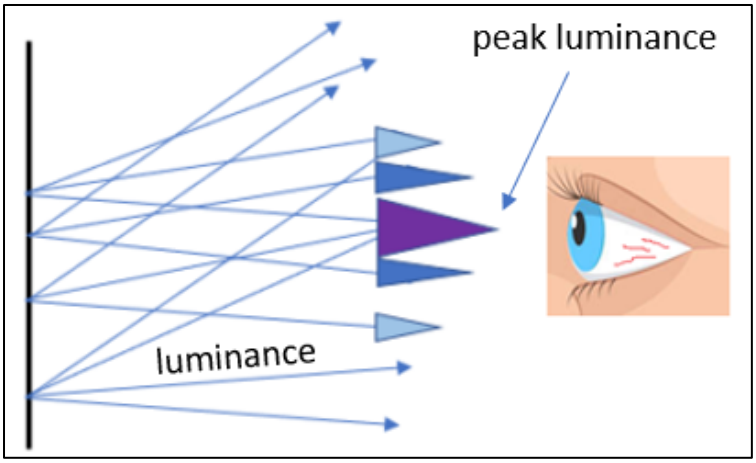


Figure 15

Because the light is emitted from a flat surface, the brightness is measured in nits (candela per square meter), and not luminous intensity as with a curved surface emitter.[20] This is why LED electronic displays advertise brightness with the number of nits. (LED headlights and LED streetlights should also specify their brightness in nits). A single value for luminance cannot be used for a flat surface emitter; however, we can state a "peak luminance" that quantifies the maximum luminance emitted by the chip. An LED light source cannot be modeled as an infinitely small mathematical point (point source) because the emitter geometry is flat, not curved, and the resulting radiation will always retain the Lambertian spatial energy shape, no matter how far away the viewer is from the source.

An LED emits visible radiation in a tight beam. Within that beam, the energy is spatially non-uniform. Even at a distance, for example many kilometers away, the light will remain dense, with little dispersion and little scattering, depending on environmental conditions. While light from a curved surface disperses following an inverse square law, flat surface sources focus the light into a narrow beam. For LEDs, the luminance metric is used to measure brightness at the source of the light in near field, and there will be a different luminance value for each point in space. Generally, these measured near-field luminance values will be unchanged at the destination, such as at the eye. For example, a peak luminance of 1,000,000 nits measured at the chip will still be 1,000,000 nits at an observer's eye 30 meters from the LED light source.

Comparison of Curved Surface and Flat Surface Emitter

A curved surface emitter such as a tungsten filament will emit essentially spatially uniform isotropic radiation as shown in (a) and (c) of Figure 16. A flat surface emitter such as an LED will emit spatially non-uniform anisotropic radiation, as shown in (b) and (d).

[20] https://ocw.snu.ac.kr/sites/default/files/NOTE/791.pdf

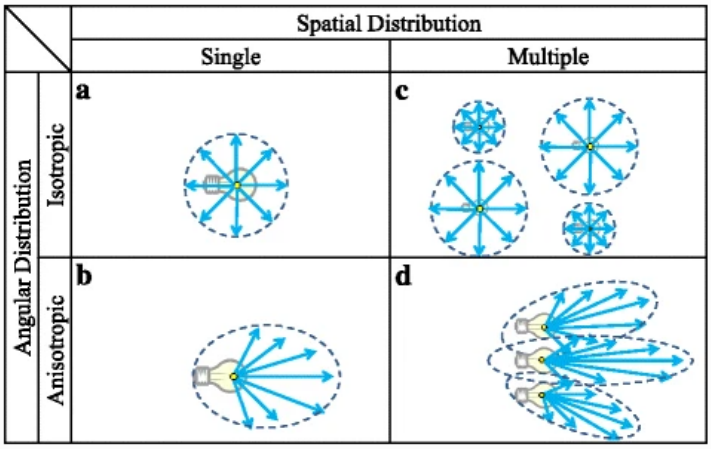


Figure 16 - Isotropic vs. Anisotropic[21]

Figure 17 shows a cross section of the radiation emitted from a light source as it lands on a surface. Isotropic radiation such as from a tungsten filament or gas-discharge light source will create a uniform distribution of light, whereas the anisotropic radiation emitted from a flat surface LED will create non-uniform light distribution, with much of the radiation concentrated in the center. The precision needed to measure the distribution of LED radiation is on the femtometer or picometer scale.

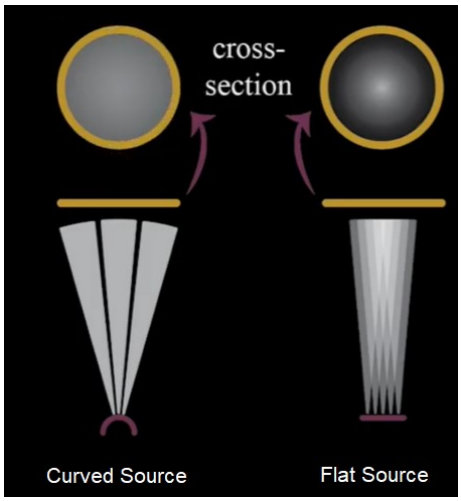


Figure 17 - Spatial Distribution Comparison[22]

M. Nisa Khan has a Ph.D. in electrical engineering, and B.S. in physics and mathematics and is a renowned expert in flat surface LED emitters. She is the author of Understanding LED Illumination. Figure 18 from Dr. Khan's book shows the fundamental difference between a flat surface emitter and curved surface emitter.

[21] https://ipsjcva.springeropen.com/articles/10.1186/s41074-016-0014-z
[22] https://youtu.be/fkb1zeoXIug

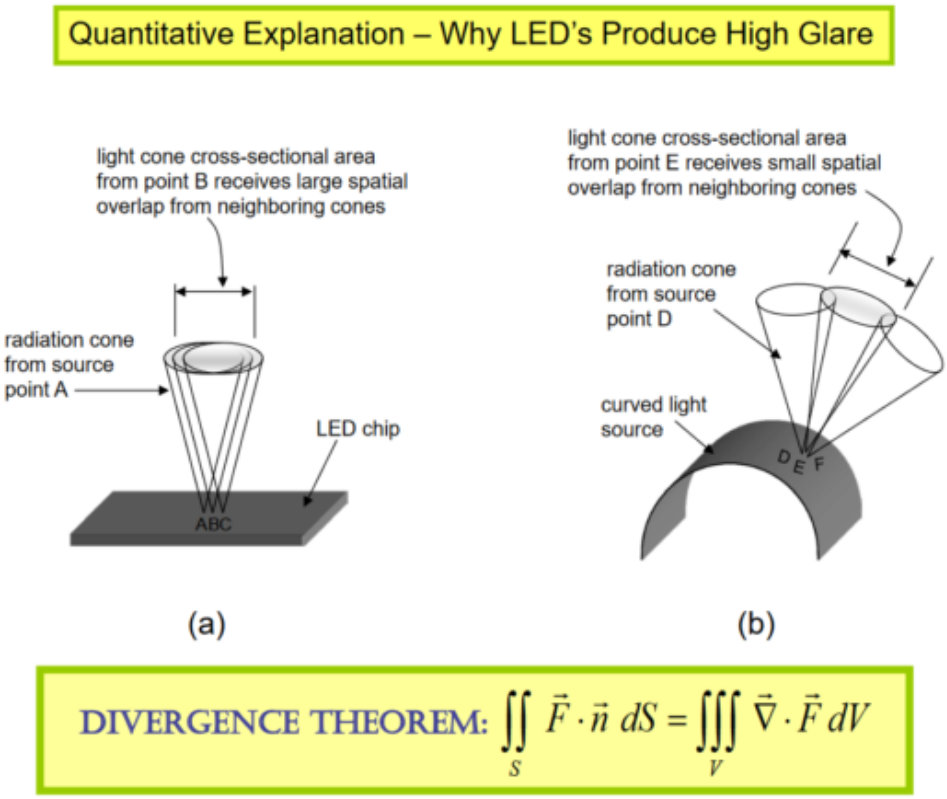


Figure 18 - Flat vs. Curved Surface Emissions[23]

Peter Veto has a Ph.D. in psychophysics and has produced several instructive videos on the topic of LED luminance and glare.

1. Why are LED headlights so glaring? | Part 1: Luminance - https://youtu.be/fkb1zeoXIug
2. Why are LED headlights so glaring? | Part 2: Color (spectral power distribution) - https://youtu.be/YINHa_zwFQs
3. Demo: LED vs. halogen apparent luminance distribution - https://youtu.be/9TZG49xoClo

In summary, metrics previously used for curved surface emitters such as tungsten filament and gas-discharge lamps cannot be used for flat surface emitters. The brightness of a flat surface emitter is measured via peak luminance in nits (candela per square meter). LED visible radiation is spatially non-uniform. NHTSA must update FMVSS-108 to include metrics for flat surface LED emitters or simply, and more safely, prohibit the use of LEDs as vehicle headlights. Ford's claim that LED headlights produce a type of light that is regulated by FMVSS-108 is false.

[23] Understanding LED Illumination, CRC Press, 2013, pg. 170

VI. Relief Requested

We have shown that Ford's LED headlights do not comply with either the Motor Vehicle Safety Act or 1966 or the Federal Motor Vehicle Safety Standard 108. We have also shown that Ford has failed to comply with the Administrative Procedure Act of 1966 and that the National Highway Traffic Safety Administration has failed in its duty to investigate Ford's claims that their LED headlights comply with FMVSS-108. We have provided the necessary evidence to show that there is probable cause to investigate Ford's false claims that their self-certification process for LED headlights produces valid results.

Therefore, the Soft Lights Foundation hereby requests that the Department of Transportation, Office of Inspector General initiate an investigation into Ford's failure to manufacture vehicles with headlights that comply with federal safety regulations and the Federal Motor Vehicle Safety Act. We request that the OIG use an outside, independent investigator that has the required expertise related to the spatial properties of flat surface LED visible radiation sources.

Respectfully Submitted,

/s/ Mark Baker
B.S., Electrical Engineering, University of California, Santa Barbara
President, Soft Lights Foundation

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1. 4-D Light Field Reconstruction by Irradiance Decomposition - https://ipsjcva.springeropen.com/articles/10.1186/s41074-016-0014-z - Shows spatial difference between isotropic and anisotropic emitters.

2. Derivation and Experimental Verification of the Near-field 2D and 3D Optical Intensities From a Finite-size Light Emitting Diode (LED) - https://ieeexplore.ieee.org/document/8879542 - Shows that radiation from a flat surface is a Lambertian shape.

3. Understanding LED Illumination, M. Nisa Khan, CRC Press 2014.

4. Is Street Lighting Damaging Our Health? - https://online.flippingbook.com/view/702884488/ - Cree Lighting acknowledges that LEDs emit non-uniform luminance.

5. Light Emitting Diodes, Chapter 16, Human Eye Sensitivity and Photometric Quantities - https://ocw.snu.ac.kr/sites/default/files/NOTE/791.pdf - States that point source brightness is measured with luminous intensity in candela, and surface source brightness is measured with luminance in nits (candela per square meter).

6. The Influence of LED Emission Characteristics on the Efficiency of Lighting Systems by Osram Opto Semiconductor - https://www.led-professional.com/resources-1/articles/the-influence-of-led-emission-characteristics-on-the-efficiency-of-lighting-systems-by-osram-opto-semiconductor-1 - Describes the difference between volume and surface LED emitters and describes the spatial emissions as a Lambertian or near-Lambertian.

7. Angular Distribution of the Averaged Luminous Intensity of Low Power LEDs Transfer Standards - http://www.softlights.org/wp-content/uploads/2022/03/Lambertian-2013.pdf - LEDs emit non-uniform energy in a Lambertian shape, sometimes off-centre.

8. Healthier and Environmentally Responsible Sustainable Cities and Communities. A New Design Framework and Planning Approach for Urban Illumination - https://www.mdpi.com/2071-1050/14/21/14525/htm - Artificial light is having significant negative consequences on human and biological health. Over 100 references to research studies.