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January 11, 2023

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FILING DATE: *July 30, 2021*
PATENT NUMBER:
ISSUE DATE: *August 19, 2022*

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	
Filing Date	
First Named Inventor	Yechezkal Evan Spero
Art Unit	N/A
Examiner Name	N/A
Attorney Docket Number	TRCH0102RX

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	3,316,442	A	1967-04-25	Konrad	
	2	6,406,172	B1	2002-06-18	Harbers et al.	
	3	6,587,573	B1	2003-07-01	Stam et al.	
	4	6,861,809	B2	2005-03-01	Stam	

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U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
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FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]

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	Examiner Name	N/A
	Attorney Docket Number	TRCH0102RX

	1	2001070538	WO	A2	2001-09-27	Stam et al.		☐
	2							☐

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NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
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Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	
	Filing Date	
	First Named Inventor	Yechezkal Evan Spero
	Art Unit	N/A
	Examiner Name	N/A
	Attorney Docket Number	TRCH0102RX

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Sangeeta G. Shah/	Date (YYYY-MM-DD)	2021-07-30
Name/Print	Sangeeta G. Shah	Registration Number	38,614

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

YECHEZKAL EVAN SPERO

Patent No.: 9,955,551

Control No.: N/A

Filed: July 30, 2021

Group Art Unit: N/A

Examiner: N/A

Request for Reexamination Under U.S.C §§ 302-307 and 37 C.F.R. §1.510

For: DETECTOR CONTROLLED ILLUMINATING SYSTEM

Attorney Docket No.: TRCH0102RX

PATENT OWNER REQUEST FOR *EX PARTE* REEXAMINATION
OF U.S. PATENT NO. 9,955,551 INCLUDING AMENDMENT

Mail Stop *Ex Parte* Reexamination
Attn: Central Reexamination Unit
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

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... *electronic circuitry apparatus for the controlled powering of the light source and other illuminating device elements;* 40
... *one or more cameras placed on the structure for detecting coordinate-specific information about the illuminated area, said camera in communication with power and control device elements;* 46
... *a controller integrated with the structure, in communication with the light source controlling power circuitry, said controller arranged to processes the information communicated from the*

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EXHIBIT LIST

Exhibit No.	Description
PAT-A	U.S. Patent No. 9,955,551 Spero
PA-A	International Publication No. WO 01/70538 Stam PCT
PA-B	U.S. Patent No. 6,406,172 Harbers et al.
PA-C	U.S. Patent No. 6,281,632 Stam et al.
PA-D	U.S. Patent No. 6,587,573 Stam et al.
PA-E	U.S. Patent No. 6,861,809 Stam et al.
SB08	U.S. Patent and Trademark Office form SB08
OTH-A	Stam Declaration
OTH-B	Stam C.V.
OTH-C	New Claims
OTH-D	Support for proposed amendments
OTH-E	Industry praise nexus support document
OTH-F	Side by side comparison
OTH-G	European Patent No. EP1391347 B1 Krukenbaum et al.
OTH-H	U.S. Patent No. 6,752,523 Takahashi

OTHER EXHIBITS AND SUPPORTING DOCUMENTATION

Exhibit No.	Description	Identifier
Exhibit 1	Vijayenthiran, Vinesh, "A look at the new LED headlights on the Lexus LS600H," May 14, 2007 https://www.motorauthority.com/news/1027394_a-look-at-the-new-led-headlights-on-the-lexus-ls600h, permalink https://perma.cc/Y8XS-GAA8	Motor Authority
Exhibit 2	Wayback Machine – Internet Archive, "LED headlights – Audi Technology Portal," November 16, 2014 https://web.archive.org/web/20141116034803/https://www.audi-technology-portal.de/en/electrics-electronics/lighting-technology/led-headlights, permalink https://perma.cc/7W6N-D6T9	Audi Technology Portal
Exhibit 3	Tamburo, R. et al. (2014) "Programmable Automotive Headlights", http://www.cs.cmu.edu/~ILIM/publications/PDFs/, permalink https://perma.cc/4SXQ-KXVA	Tamburo R. (2014)
Exhibit 4	NHTSA Proposed Rule 2018 Published in Federal Register, Vol. 83, No. 198, Friday October 12, 2018, permalink https://perma.cc/57ZR-WSX2	NHTSA Proposed Rule 2018
Exhibit 5	WayBack Machine – Internet Archive, "Koito Company History" https://www.koito.co.jp/english/corp/history/chronology.html First archive captured via WayBack Machine October 24, 2020 at 5:20 and 18 seconds https://web.archive.org/web/20201024172018/https://www.koito.co.jp/english/corp/history/chronology.html, permalink https://perma.cc/8HAW-S2SH	Koito
Exhibit 6	WayBack Machine – Internet Archive, "HELLA Company History" First archive captured via WayBack Machine March 25, 2016 at 03:25 and 44 seconds https://web.archive.org/web/20160325044139/https://www.hella.com/hella-com/en/History-739.html, permalink https://perma.cc/8YR7-WF6H	HELLA
Exhibit 7	Teague, Chris. "Here's How Smart Headlights Work," April 14, 2021, https://www.autoweek.com/news/technology/a36031601/heres-how-smart-headlights-work/, permalink https://perma.cc/QQ2G-F3BH	Autoweek

Exhibit No.	Description	Identifier
Exhibit 8	Wayback Machine – Internet Archive, "AAA Research Report European Specifications vs US Headlamps," April 2019 First archive captured via WayBack Machine April 12, 2021 at 5:07 and 23 seconds https://web.archive.org/web/20210412050723/https://newsroom.aaa.com/wp-content/uploads/2019/06/ResearchReportEuroSpecvsUSHeadlamps.pdf and https://newsroom.aaa.com/wp-content/uploads/2019/06/ResearchReportEuroSpecvsUSHeadlamps.pdf, permalink https://perma.cc/ULR2-HZ98	AAA 2019 report
Exhibit 9	WayBack Machine – Internet Archive, "Two Interesting New Lighting Systems from BMW," Driving Vision News, December 3, 2019 First archive captured via WayBack Machine July 13, 2021 at 12:42 and 04 seconds https://web.archive.org/web/20210713144204/https://www.drivingvisionnews.com/news/2019/12/03/two-interesting-new-lighting-systems-from-bmw/ and https://www.drivingvisionnews.com/news/2019/12/03/two-interesting-new-lighting-systems-from-bmw/, permalink https://perma.cc/PVR3-3PKD	Driving Vision News
Exhibit 10	WayBack Machine – Internet Archive, "HELLA's LED Matrix Lighting Wins Automotive News PACE Award" PR Newswire April 8, 2014 First archive captured via WayBack Machine April 11, 2014 at 11:19 and 57 seconds https://web.archive.org/web/20140411221957/https://www.prnewswire.com/news-releases/hellas-led-matrix-lighting-wins-automotive-news-pace-award-254371771.html and https://www.prnewswire.com/news-releases/hellas-led-matrix-lighting-wins-automotive-news-pace-award-254371771.html, permalink https://perma.cc/79QJ-EZZU	PR Newswire
Exhibit 11	Alliance for Automotive Innovation submission August 5, 2020 Retrieved from https://www.regulations.gov/comment/NHTSA-2018-0090-0219, permalink https://perma.cc/8HX8-DZPA	Alliance for Automotive Innovation

I. Introduction

Yechezkal Evan Spero ("Spero"), Patent Owner, requests reexamination of claim 6 of U.S. Patent No. 9,955,551 ("the '551 Patent") in light of a substantial new question of patentability raised by prior art not considered by the examiner during prosecution of the '551 Patent, specifically International Publication No. WO01/70538 ("Stam PCT"), and U.S. Patent No. 6,406,172 ("Harbers"). Patent Owner also submits new claims 24-87, which narrow base claim 6.

Accordingly, the Patent Owner requests that the Office find a substantial new question of patentability with respect to claim 6, order reexamination, and issue a reexamination certificate confirming the patentability of claim 6 in addition to the proposed new claims submitted herewith.

II. Requirements for *Ex Parte* Reexamination Under 37 C.F.R. § 1.510

Patent Owner satisfies each requirement for *ex parte* reexamination of the '551 Patent as stated below.

A. 37 C.F.R. § 1.510(b)(1): Statement Pointing Out Each Substantial New Question of Patentability

A statement pointing out each substantial new question of patentability ("SNQ") based on the cited patents in accordance with 37 C.F.R. § 1.510 (b)(1) and (b)(2) is provided in Section VII.

B. 37 C.F.R. § 1.510(b)(2): Detailed Explanation of the Pertinency and Manner of Applying the Prior Art

See Sections IV, VII and IX.

C. 37 C.F.R. § 1.510(b)(3): Copy of Every Patent or Printed Publication Cited Against the Claims

Exhibits PA-A and PA-B are the Stam PCT Publication and Harbers respectively:

PA-A Stam PCT

PA-B Harbers

References PA-A and PA-B are also listed on Exhibit SB08 (*i.e.*, Form PTO-SB/08.)

D. 37 C.F.R. § 1.510(b)(4): Copy of the Entire Patent

A full copy of the '551 Patent is submitted herein as Exhibit PAT-A in accordance with 37 C.F.R. §1.510(b)(4).

E. 37 C.F.R. § 1.510(a): Fee for Requesting Reexamination

In accordance with 37 C.F.R. § 1.510(a), the reexamination fee has been paid as part of the EFS-WEB submission. Any deficiency or overpayment may be debited/credited to Deposit Account No. 023978.

F. Related Matters

The following is a current list of all matters involving the '551 Patent:

U.S. Patent Application 15/961,861 filed on April 24, 2018, which issued on January 19, 2021 as U.S. Patent No. 10,894,503 is a continuation of the '551 Patent. U.S. Patent Application 16/853,342 filed on April 24, 2020 is a continuation of the '551 Patent and is currently pending.

Reissue application, 16/858,342, was filed on April 24, 2020. This broadening reissue application includes a total of 44 claims, including claim 6 of the original '551 Patent, which is also included in this reexamination request. Accordingly, while there may be some overlapping subject matter, the newly added and currently pending reissue claims relate to light sources for illuminating subareas of an interior space and more specifically, claims directed to a room-illumination system for adjusting light responsive to lighting characteristics within a room. In contrast, the proposed new claims in this request for *ex parte* reexamination narrow claim 6.

If this request for *ex parte* reexamination results in a determination and order for *ex parte* reexamination under 35 U.S.C. § 1.525, it will result in concurrent office proceedings, under 37 C.F.R. § 1.565 and MPEP § 2285. Merger of the reissue and *ex parte* reexamination proceedings is, however, inappropriate in this particular situation because merger would result in "the patent

owner [being] required to place and maintain the same claims in the reissue application and the *ex parte* reexamination proceeding during the pendency of the merged proceeding." As the reissue application is a broadening reissue, the new claims are broader and different than the originally issued patent claims – thus, by statute, the new claims are not subjectable to consideration in an *ex parte* reexamination proceeding. Accordingly, a merged proceeding is statutorily impermissible as these claims cannot be permissibly added to the reexamination proceeding to maintain matching claim sets.

A stay of either proceeding is also inappropriate, in view of the requirement to conduct reexamination and reissue proceedings with "special dispatch" per 35 U.S.C. § 305 and MPEP § 2261. As the reissue application was filed over one year ago and has not received an office action to-date, any further delay would significantly prejudice patent owner's ability to obtain additional claims within the '551 Patent term, which expires in January, 2026. Given the limited patent term remaining, stay of either the *ex parte* reexamination or reissue proceeding would lead to significant prejudice to the patent owner.

Finally, should a minor inconsistency arise between the two concurrent proceedings, it can be readily rectified by a housekeeping amendment, prior to issuance.

III. Claim Construction

A. Standard of Claim Construction

In an *ex parte* reexamination, claims are to be given their "broadest reasonable interpretation" consistent with the specification and consistent with the interpretation that those skilled in the art would reach. MPEP § 2111. The "broadest reasonable interpretation does not mean the broadest possible interpretation." *Id.* Notwithstanding the broadest reasonable interpretation rubric, the Federal Circuit has repeatedly rejected PTO constructions that are

"unreasonably broad" and "inconsistent" with the language of the specification. *In re Suitco Surface, Inc.*, 603 F.3d 1255, 1260 (Fed. Cir. 2010); *see also TriVascular, Inc. v. Samuels*, 812 F.3d 1056, 1062 (Fed. Cir. 2016) ("Construing words of a claim without considering the context in which those words appear is simply not 'reasonable'; Furthermore, "[w]hile the broadest reasonable interpretation standard is broad, it does not give the Board an unfettered license to interpret the words in a claim without regard for the full claim language and the written description."). A patent applicant may consistently and clearly use a term in a manner either more or less expansive than its general usage in the relevant art, thereby expanding or limiting the scope of the term in the context of the patent claims. *See SciMed Life Sys., Inc. v. Advanced Cardiovascular Sys., Inc.*, 242 F.3d 1337, 1343–44 (Fed. Cir. 2001).

B. Summary of Claim Construction Position

As detailed in the Stam declaration and consistent with the specification in the '551 Patent and the usage of the term in the claims, a person of ordinary skill in the art (POSITA) would understand the term *light source* to mean individual LED.[1] (Ex. OTH-A, "Stam Decl." at ¶20.)

Per the '551 Patent, the "invention comprises a novel multi-light source approach to the design and construction of **solid-state lighting fixtures** (vs. solid-state lamps), which is termed a "**Digital Lighting Fixture**" **due to the control of individual lighting element "digits"** to provide the "correct" lighting solution for the situation at hand." (Ex. PAT-A, '551 Patent at 11:8-13, emphasis added.[2])

---

[1] For ease of reference, italicized font is used throughout to connote claim language.

[2] Notably, a person skilled in the art understands that HID is the abbreviation for high-intensity discharge (HID) lamps, which are a type of electrical gas-discharge lamp which produces light by means of an electric arc between tungsten electrodes housed inside a translucent or transparent fused quartz or fused alumina arc tube. (Ex. OTH-A at 12, fn 2.)

As the Detailed Description of the '551 Patent makes clear,

> **[t]he system is built around a "digital" light source**. That is, the emanating lighting effect is **the sum of the characteristics of a multiplicity of discretely controllable "digit" sources**. The difference between the **individual** "digit" **light sources** and their summation manifests itself in the resultant light characteristic, be in its intensity, spatial intensity distribution, spectral energy content and spectral intensity distribution. . . Therefore, the illuminating device may be described as a "digital" **light source** or as a Multiple Solid-state Light Source (MSLS), comprising many "digits," SLSs, and **essentially replaces the lamp of present-day luminaires**.

(Ex. PAT-A at 16:39 – 17:2, emphasis added.) Notably, "a person of ordinary skill in the art understands that a solid-state light source (SLS) uses light-emitting diodes as a light source, rather than electrical filaments, plasma or gas." (Ex. OTH-A at ¶20.)

The '551 Patent explains how the "digital aspect" of the illuminating device gives rise to "digital" "control capability" for individual LEDs or selectable groups of LEDs:

> The multiple light sources of specific characteristics provide quanta of power and spectrum which are smoothly added or detracted to generate a changed lighting effect. The digital aspect arises from the sufficient progression of values, varying by minutes to produce a continuum so as to be non-discernable or irrelevant to the user. **The added controllability is realized by breaking up the light-production, into discrete, specifically aimable, and dimmable elements which can be addressed by control electronics** for the purpose of affecting the intensity, spectrum and spatial distribution of spectrum and of intensity of the illumination provided by the luminaire of the present invention.
>
> The overall combination of control capability and discrete light sources yields a digital lighting fixture. The terminology "digital" as used herein refers to the discrete nature of the multiple LED lamps provided in the luminaire, whereby **"digital" control results from the individual control of the discrete, i.e.** "digital"

lighting elements, the LEDs, in the luminaire.

(Ex. PAT-A at 2:51-3:3, emphasis added; Ex. OTH-A at ¶21.)

The specification of the '551 Patent further demarcates the invention in relation to the prior art:

> **[t]he advance over prior art is a solid-state light source with increased**: 1. Efficiency—more effective lumen per watt electricity. 2. Durability—physical strength, life expectancy, lumen maintenance and spectral stability. 3. Lighting quality—as related to visual comfort and "atmosphere." 4. Functionality—ability to control the light placement, intensity and color temperature and do so as needed. 5. Energy savings 6. Lower overall lifecycle cost.

(Ex. PAT-A at 11:66-12:6, emphasis added.)

More specifically, the specification makes it clear that the desired control functionality is facilitated by the ability to break "the total light output into discrete (digital) specifically aimable and dimmable elements" and determine the "selection and placement of light sources" for the "correct lighting practice":

> **Integrating the light source with power conditioning electronics, control circuitry and sensors gives additional cost benefits and functionality including**: 1. Mass production capability 2. Sealed-for-life fixture 3. Exact optical performance less spill light 4. Compact design 5. Feedback control and recalibrated color consistency over the device lifetime 6. Real-time lighting needs adaptability.**...**
>
> **...**
>
> In summary, as opposed to **LED industry trends of going with a single large source, the present invention provides multiple smaller sized sources** of differing characteristics such that their combined effect is greater than that which could have been offered by sum of the individual parts operating separately. The added **controllability offered by breaking the total light output up into discrete**

("digital") specifically aimable and dimmable elements which can be addressed by control electronics to effect intensity, spectrum and spatial distribution of intensity and spectrum, yields a lighting fixture (vs. lamp) of unparalleled performance.

...

Unique to this patent is the approach. It is the approach of a lighting manufacturer who provides lighting solutions versus that of a lamp manufacturer who produces a generic lamp.

...

The process includes **determining: the correct lighting practice for the application; the surroundings; the selection and placement of light sources** and their integration with the mechanical support and; electronic control elements to realize the objective.

(Ex. PAT-A at 12:7-13, 24:37-47, 11:62-65, 13:63-65, emphasis added; Ex. OTH-A at ¶22.)

The specification of the '551 Patent also ties control functionality to the ability to "adjust power to SLS":

In a preferred embodiment the DLF contains **logic control electronics unit 7. Logic control electronics unit, 7, receives input and/or feedback from motion, intensity and/or spectral sensors 8, or from manual control button 9 and increases or decreases or turns on or shuts off the power to one or more of the SLS to effect the desired change**. That is, the control logic unit 7 has stored parameters for intensity and spectral distribution and operates the MSLS lamp within the predefined range. The control unit may include a DSP or computer with storage media, computer algorithms, signal input and output electronics, analog to digital converters, and communications elements to carry out intensity, distribution, dimming and color balance control. Computer algorithms and instruction sets 7A are induced by the logical controller to manipulate data, calculate results generate output signals and maintain the operating parameters within the specifications. **Measured parameters are checked against the store parameters and the**

control circuitry adjusts the power to SLS.

(Ex. PAT-A at 25:34-52; Ex. OTH-A at ¶22.)

Finally, the Field of the Invention expressly excludes traditional lighting sources: "[t]he invention relates to multiple light source illuminating devices **intended to replace** incandescent, fluorescent and HID luminaires in general and specialty lighting applications." (Ex. PAT-A at 1:33-35, emphasis added; Ex. OTH-A at ¶23.) While the specification provides a "laundry list of potential light sources" at 16:47-51, when read in the context of the overall specification and the usage of the term *light source* in the claims, the proffered construction follows. (Ex. OTH-A at ¶24.) Construing the term *light source* to include incandescent, fluorescent and HID light sources "doesn't make sense" in reference to the claims—see for example, claim 1 which requires a *multiplicity of independently controllable light sources*. (*Id.*)

Thus, pursuant to the broadest reasonable construction rubric, consistent with the teachings in the specification and the claim language, a person of ordinary skill in the art would construe the claim term *light source* to mean an individual LED. (Ex. OTH-A at ¶25.)

IV. Background of Automotive Lighting Industry

The state of the automotive lighting industry in 2001-2002 can be gleaned from prior art patent filings. One reference in particular, U.S. Patent No. 6,281,632, filed on April 2000 and issued to *Stam et al.* (Ex. PA-C, "Stam '632"), serves as a guidepost on development efforts and the state of expert knowledge during the relevant time period. (Ex. OTH-A at ¶27.)

As of 2001, researchers were developing technologies for continuously variable headlamps, able to change the intensity of light and/or the direction of light emitted by the headlamps. (Ex. PA-C at 1:21-24.) According to the '632 patent, the intensity of headlamp illumination could be "accomplished in several different" ways by: 1) providing "a pulse width

modulated (PWM) signal to the headlamp and "varying the duty cycle of the headlamp power," 2) providing a "PWM signal to a lamp driver integrated circuit," 3) through high intensity discharge (HID) headlamps—" a new, highly efficient headlamp technology"—wherein "ballasts used to power HID lamps can be directly supplied with a control signal to vary headlamp illumination intensity"; and 4) providing "an attenuating filter to absorb some of the light emitted from the headlamp." (Ex. PA-C at 1:26-48; Ex. OTH-A at ¶27.) As the '632 patent filing evidences, there were also several known means for changing the direction of light emitted from headlamps:

> Headlamp aim can be varied using actuators [such as stepper motors] to move the headlamp housing relative to the vehicle. . .For headlamps with appropriately designed reflectors, mechanically moving the light source relative to the reflector can change headlamp beam direction as well as headlamp illumination intensity. Additionally, with HID headlamps, the headlamp beam can be aimed by "deflecting or perturbing the arc in such a way as to vary the lamp output.

(Ex. PA-C at 1:52-65; Ex. OTH-A at ¶28.)

During the relevant time, industry experts were also interested in continuously variable headlamps:

> Automatic control of continuously variable headlamps offers several potential benefits over automatic control of traditional on-off headlamps. Greater flexibility for illumination is available, allowing headlamp illumination to be better adapted to driving conditions. Also, continuously varying the headlamp illumination does not create rapid changes in illumination that may startle the driver.

(Ex. PA-C at 2:13-19; Ex. OTH-A at ¶29.)

Per the '632 patent, "one of the oldest methods [for a continuously variable headlamp] is to aim the headlamp in the same direction as steered wheels. Another method increases the

illumination range in proportion to vehicle speed." (Ex. PA-C at 2:22-24; Ex. OTH-A, at ¶30.) "Still another method of controlling headlamps has been developed for HID lamps. The increased brightness and blueish color of the HID lamps is particularly disrupting to oncoming drivers. Due to this disruptness effect, certain European countries require headlamp leveling systems." (Ex. PA-C at 2:25-29; Ex. OTH-A at ¶31.)

In addition to benchmarking the state of automotive lighting development, the specification of the '632 patent identified a persistent deficiency with continuously variable headlamps: "One problem with current continuously variable headlamp control systems is the inability to consider oncoming or leading vehicles in determining the illumination range of the headlamps." (Ex. PA-C at 2:35-38; Ex. OTH-A at ¶32.) Per the '632 patent, prior art solutions to modify illumination in view of oncoming and leading vehicles suffered from several problems. In particular, prior art systems lacked "color discriminating capability" and thus prior art imaging systems were "incapable of accurately determining lateral and elevational locations of headlamps or tail lights at any distance." (Ex. PA-C at 2:54-60; Ex. OTH-A at ¶32.)

To address the above-identified problem, Joseph S. Stam and his colleagues at Gentex Corp filed US 09/800,460 in March, 2001, which issued as U.S. Patent No. 6,587,573 (Ex. PA-D, "Stam '573") in July, 2003. Stam '573 focused on how to improve automatic high beam dimming functionality by improving image detection capability using an image array sensor to 1) distinguish "nuisance" light sources, taillights and oncoming lights to avoid unnecessary switching to low beams; and 2) develop a more intelligent set of automatic high beam controls of halogen/HID light sources based on the location of detected objects. (Ex. PA-D; Ex. OTH-A at ¶33.)

In his declaration, in reference to Stam '573 and its related filings ("'573 Family of Patents"), Stam states that the "patent applications I filed during this time describe detailed

methods for distinguishing "nuisance" light sources, such as reflectors, street signs, streetlights and house lights, from taillights and oncoming headlight sources using a coordinate-specific image array sensor and microprocessor that employs various algorithms using location, brightness and color information." (Ex. OTH-A at ¶34.) Per Stam, these filings specifically outline image detection control strategies to adjust illumination to avoid glare based on the identification or type of detected objects by 1) turning them on/off or varying the intensity of the light sources and 2) changing the direction of the light sources using motors. (Ex. OTH-A at ¶35.) Exemplary illumination patterns are shown in Figs. 50A-50C of the '573 Patent. (Ex. PA-D Figs. 50A-50C; Ex. OTH-A at ¶35.)

As Stam explains in his declaration, in the '573 Family of Patents, "the auto high beam control teachings contemplated halogen or HID light sources as those technologies were proven and reliable at the time." (Ex. OTH-A at ¶36.) Stam goes on to state that while he was working at Gentex, "high-powered white light LED technology was still in a nascent stage, with LED experts working on improvements to lamp technology and the related supportive environment needed for LED applications." (Ex. OTH-A at ¶36.) "LEDs suffered from several technical constraints at the time, with issues related to product variability, power restrictions, thermal load requirements, production of white light and lighting output." (*Id.*) Stam further provides that "[a]lthough LEDs were known to be more energy efficient, the technology was overly complex, unreliable and too costly for front headlights." (Ex. OTH-A at ¶37.)

Thus, in 2003 and for several years thereafter, "those skilled in the art of auto headlight design and controls used LEDs for taillights and interior spotlights but not front headlights." (*Id.*) By way of example, EP1391347, filed in July, 2003 by HELLA (a global developer and manufacturer of automotive lighting), is directed to a pivoting, auto high-beam lamp devoid of any

teaching of the use of LEDs and U.S. Patent No. 6,752,523 filed in October 2002 by Koito (a global developer and manufacturer of automotive lighting), discloses the use of LEDs for taillights but not headlights. (*Id.*) LED headlights were first used in vehicles in 2007-2008. *See*, Toyota's use of a partial LED headlight in 2007 and Audi's introduction of full LED headlights in 2008. (Ex. 1 Motor Authority; Ex. 2 Audi Technology Portal; Ex. OTH-A at ¶38.) *See*, Koito's development chronology, which lists "Production and sales of the world's first LED Headlamps" in May 2007; HELLA's product history timeline, which lists "HELLA develops the first full LED headlamp for the Cadillac Escalade Platinum" in 2008 and "First full LED headlamp with AFS functions Audi A8" in 2010. (Ex. 5 Koito at 1; Ex. 6 HELLA at 1; Ex. OTH-A at ¶38.)

V. The Prior Art Asserted References

A. Stam PCT

Stam PCT (WO 01/70538), filed on March 20, 2001, is part of the '573 Family of Patents. (Ex. PA-A at 1.) Stam PCT is directed to a system for controlling exterior vehicle lights, wherein the control system "comprises an imaging system configured to image the scene forward the controlled vehicle, and a control circuit for processing the image of the scene obtained from the imaging system and for controlling the exterior lights to change their beam pattern in response to objects detected in the processed scene." (Ex. PA-A at 2-3.)

Per Stam PCT, the control circuit can turn the lights on/off or change brightness and aim to produce beam patterns that avoid causing excessive glare:

> Ideally the exterior lights are controlled such that if an observer is located in a vehicle within a 'glare area' relative to the vehicle (i.e., the area in which the observer would perceive the brightness of the exterior lights as causing excessive glare), the beam illumination pattern is varied such that the observer is no longer in the glare area. The perceived brightness and/or glare area of the headlamps (and/or

other exterior lights) may be varied by changing the illumination output of the one or more of the lights forming the headlamps, activating or deactivating some or all of the lights, altering the illumination pattern forward of the vehicle, or a combination of the above.

(Ex. PA-A at 9; Ex. OTH-A at ¶47.)

As Stam explains in his declaration, in reference to the above excerpt, "activating or deactivating 'some or all of the lights' refers to low beam, high beam or side bending lights, which is distinct from any teaching involving individual light emitters within a lamp." (Ex. OTH-A at ¶48.)

As outlined in Stam PCT, the known technical constraints with LEDs in 2001-2002, limited LED usage in headlights:

> It has long been considered to be desirable to provide headlamps that can be steered in the direction that the vehicle is turning. It is also desirable to provide forward lighting that can be turned OFF, or substantially attenuated, for such a short period of time that the driver does not notice that the lights are OFF. In this way, reflections do not exist during image acquisition. Although a light emitting diode (LED) lamp can be used to provide these features in a cost-effective manner, LED lamps producing enough light to implement a vehicle headlamp are not commercially available. LEDs suffer from a number of disadvantages that limit their application in vehicle headlamps, not the least of which are the relatively small amounts of light produced by LEDs and manufacturability limitations when incorporating LEDS having exotic constructions. Because of these disadvantages, LED lamps have not been used to implement a vehicle headlamp despite the fact that LEDs are more rugged, more energy efficient, and significantly longer lasting than other light technologies. Additionally, means of producing white light from LEDS have only recently become practical as discussed in U.S. Patent No. 5,803,579, entitled ILLUMINATOR ASSEMBLY INCORPORATING LIGHT EMITTING DIODES, issued to John K. Roberts et al. on September 8, 1998.

(Ex. PA-A at 72-73, emphasis added; Ex. OTH-A at ¶50.)

As a result of the technical issues with LEDs in 2001-2002, the Stam PCT disclosure is limited to two LED applications that could be used as a complement to and/or as a substitute for halogen/HID light sources, to address specific imaging challenges and improve auto high beam functionality. (Ex. OTH-A at ¶51.) More specifically, though the Stam PCT teachings are directed to halogen/HID light sources, it discloses two limited uses for LED applications—to address flashing and steering:

> One of these LED applications focuses on the problem of flashing, which occurs when reflections off an object, such as a sign, are misinterpreted by the image sensor as an oncoming vehicle and trigger disruptive, rapid high/low beam flashing (repeatedly turning high beams on and off). As one solution for headlamp flashing, we contemplated the use of LEDS to rapidly reduce the light levels or turn the LEDS off, during an image-sampling interval, so that the reflections do not exist or interfere with image acquisition and processing. If done fast enough, the driver would not notice the change in light levels and the problem of flashing would be rectified. Such rapid reduction of intensity would be difficult or impossible with halogen/HID light sources.

(Ex. PA-A at 73-75; Ex. OTH-A at ¶52.)

The second LED application focused on an improved way to "steer" the light source by replacing the halogen/HID light with an LED array that could be aimed at a fixed angle for auto high beam applications. To facilitate "steering" for auto high beam applications, we disclosed use of an LED array to 1) help provide sufficient output light and 2) project light in more than one either horizontal (*see* Fig. 27) or vertical direction (*see* Fig. 28) by providing a support member with two different angled orientations. In all cases, the LED arrays were connected together and operated by a single controller, such that the entire array would be on/off or dimmed, as shown in

Fig. 26a. (Ex. PA-A at 77-79; Ex. OTH-A at ¶53.)

As the Stam declaration specifically points out, in, Fig. 26a, every optical radiation emitter (LED chip) 2603 is electrically connected together "to electrical conductor strip 2607 through a wire bond 2609 and a resistor 2611. Each of the emitters 2605 is connected to electrical conductor strip 2613 through a bonding wire 2615 and a resistor 2617." (Ex. PA-A at 74; Ex. OTH-A at ¶54.) "Since electrical conductor strips 2607, 2613 are shown to be common to multiple LED chips, they necessarily are not individually controlled or controllable." (Ex. OTH-A at ¶54.)

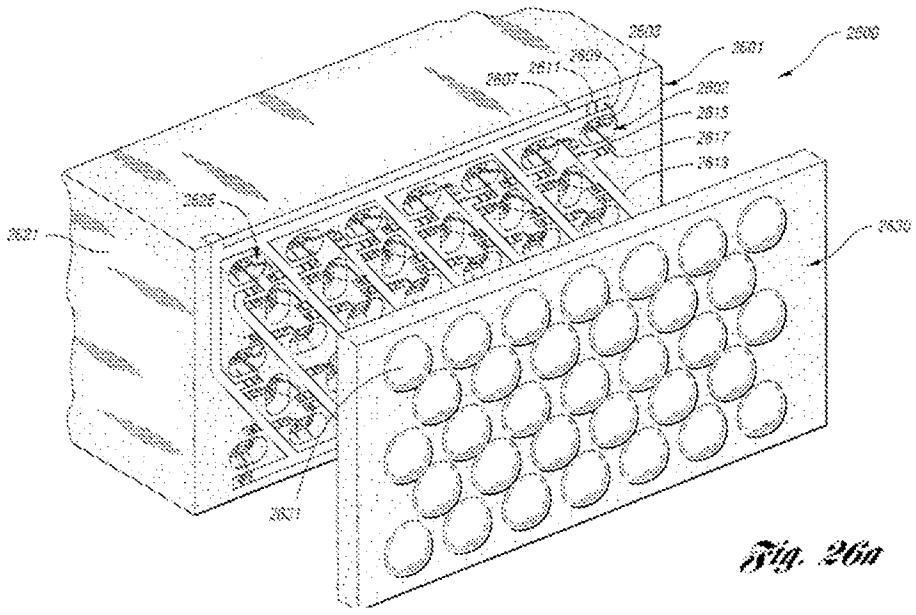


Fig. 26a

The Stam declaration further provides:

> In Figs. 50a-50c, we illustrate the types of illumination beam patterns that can be produced from the disclosed auto high beam applications. In each case, the light source is treated as a fixed block of light—whether halogen/HID or an LED array—that can be 'steered' up/down or right/left by varying the power to the LED array—

treating an array of LEDs as a unit that would be operated together.

(Ex. OTH-A at ¶55.)

Another headlamp configuration is depicted in Fig. 28, in which two LED arrays are provided, for low and high beams, and each array is treated as a single unit to be operated together:

> [a]nother alternative design for a headlamp for providing low and high beams is illustrated in Fig. 28. The headlamp 2800 includes a heat extraction member 2801 having two lamp sections 2803 and 2805. The heat extraction member 2801 is configured to include the two lamp sections 2803 and 2805, each of which is substantially identical to lamp 2601 [in Fig. 26a]. The heat extraction member provides two front faces at an angle of 1° to 2°, and may advantageously be angled at approximately 1.5°. The angle is exaggerated in Fig. 28 so that the angled surfaces are readily visible.

(Ex. PA-A at 79, emphasis added; Ex. OTH-A at ¶56.)

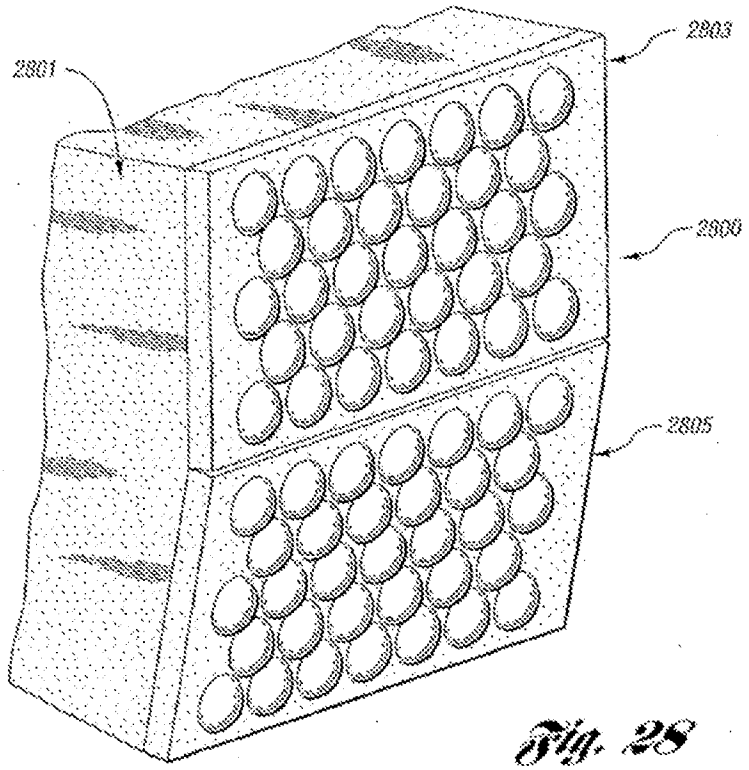


Fig. 28

In reference to Fig. 28 and the two separate LED lamp sections, 2803 and 2805 for high and low beams, the specification states: "[b]y controlling the selection of the LEDs that are illuminated, the headlamps can be aimed." As Stam make clear, "[w]hen read in context this sentence is consistent with the Stam PCT teaching that one or more LED arrays can be controlled as a single unit and in that capacity, the light from the headlamps can be steered and aimed." (Ex. OTH-A at ¶57.)

Stam also highlights the teaching absent in Stam PCT:

> [i]n the '573 Family of Patents and the Stam PCT we did not disclose a digital headlamp that included individually controllable LEDs that could be controlled to illuminate a defined coordinate-specific region. The '573 Family of Patents and Stam PCT did not teach or suggest controlling the individual LED or a selectable

group of LEDs within the array based on image detection at a given coordinate-specific location.

(Ex. OTH-A at ¶58.)

In his declaration, Stam explains how Stam PCT treated light and the resulting impact:

> While the '573 Family of Patents and Stam PCT disclosed an improved continuously variable lighting system that could adjust the intensity of the high beams and aim the headlamp beam to avoid glaring an oncoming and/or preceding vehicle, in all cases, light was treated as a fixed block to be moved or adjusted in a particular direction. As a result, the presence of one or more oncoming or preceding vehicles, would cause a driver's field of view to be lit primarily by the low beam lighting.

(Ex. OTH-A at ¶59.)

The Stam declaration also provides clarity on the use of GPS or map data in Stam PCT: Additionally, neither Stam PCT nor the '573 Family of Patents disclose use of a GPS or map data to generate coordinate-specific illumination patterns in response to upcoming road curvatures. In his declaration, Stam states:

> I mention use of GPS embodiments to determine the location of the vehicle and whether the vehicle is on a residential, country or town street, to determine whether "super" high beams were appropriate. I also disclose "bending lights" in which the light source aim is varied horizontally or separate lamps are lit to provide better illumination when turning. As with the other embodiments, I viewed each individual light source or an LED array as a single light source unit. I did not disclose individual control of the LEDs within an array into individually controlled elements or clusters. As such, I did not disclose using image detection in combination with GPS and map data to generate illumination patterns formed by individual LEDs or selectable clusters of LEDs within an array in response to

upcoming road curvatures.

(Ex. OTH-A at ¶60.)

Finally, Stam makes it clear that

> [i]t was not until US Patent No. 6,861,809 which was filed on September 5, 2002 and published on June 12, 2003 that we first described the use of individually controllable LEDs where a portion of the LEDs within an array could be dimmed or turned off to avoid glaring an oncoming vehicle.

(Ex. PA-E, Stam '809 patent; Ex. OTH-A at ¶61.)

See Fig. 7b and the accompanying description: "[a]lternatively, the window 700 may contain several independently controlled blocks 702 as shown in Fig. 7B. There may be any number of blocks, depending on the granularity of control that is desired. By selectively darkening these blocks, almost any desired beam pattern can be achieved." (Ex. PA-E at 13:6-14:3, emphasis added; Ex. OTH-A at ¶61.)

As laid out in the Stam declaration: "no other companies were offering LED headlamp technology let alone contemplating this sort of LED-to-image correlation in 2003. Given the nascent state of LED technology, those in the field of automotive lighting, were not contemplating such LED applications at the time." (Ex. OTH-A at ¶62.)

This is further evidenced by the development chronology outlined in the websites of two leading global headlamp suppliers, Koito and HELLA. (Ex. OTH-A at ¶61.) It wasn't until 2007 that the first LED headlamps were produced by Koito, and fully adaptive LED headlamps were not developed until 2010 by HELLA. (*Id.*) *See*, Koito's development chronology, which lists "Production and sales of the world's first LED Headlamps" in May 2007; Hella's product history timeline, which lists "HELLA develops the first full LED headlamp for the Cadillac Escalade

Platinum" in 2008 and "First full LED headlamp with AFS functions Audi A8" in 2010. (Ex. 5 at 1; Ex. 6 at 1; Ex. OTH-A at ¶62.)

It bears emphasis that prior to solving the issue of image detection, adaptive lighting technology that correlated the LED controls to coordinate-specific image detection was not feasible. (Ex. OTH-A at ¶63.)

B. Harbers

Harbers, U.S. Patent. No. 6,406,172 (Ex. PA-B, "Harbers '172"), is directed to a headlamp and dynamic lighting system with a light source comprising a plurality of opto-electronic elements, preferably LEDs. In Harbers, the

> spatial distribution of the light beam generated by the light source is continuously adjustable…Preferably, the spatial distribution is influenced by the speed of the vehicle, the rotational position of the steering wheel of the vehicle, the weather conditions, and it can also be influenced by the driver. Preferably, the spectral characteristics of the light beam generated by the light source depend on the position in the light beam. The light beam comprises at least two beam segments having essentially different spectral characteristics.

(Ex. PA-B at Abstract, numerical identifiers omitted; Ex. OTH-A at ¶64.)

Though Harbers is continuously adjustable by the driver or in response to a specific set of defined inputs, Harbers doesn't disclose any sensor capable of detecting objects or targets in the illuminated area. (Ex. OTH-A at ¶65.)

As Stam lays out in his declaration,

> [p]rior to the development of image detection systems--such as the kind disclosed in the '573 Family of Patents and Stam PCT— headlamp systems employed auto high beam technology that generally relied on photodiode sensors, where any incident light would activate the photodiode sensors and cause the headlamp to unnecessarily switch from high beam to low beam. As pointed out in the '573

Family of Patents and Stam PCT, the inability to discriminate between light sources minimized the effectiveness of prior art auto high beam technology.

(Ex. PA-D at 1:65 -14:3; Ex. OTH-A at ¶66.)

Similarly, prior to the image detection systems disclosed in the '573 Family of Patents, continuously variable headlamps would aim the headlamp in the same direction as steered wheels and/or increase illumination range in proportion to vehicle speed, providing variability but not in reaction to the presence of oncoming or preceding vehicles. (Ex. PA-C at 2:22-24; Ex. OTH-A at ¶66.)

VI. Overview of the '551 Patent

A. Prosecution History

U.S. Patent Application No. 13/357,549 ("the '549 application") that resulted in the '551 Patent was filed on January 24, 2012 and claims priority as a Continuation-In-Part to U.S. Patent Application No. 10/604,360, filed July 14, 2003, which was granted as US 8,100,552 on January 24, 2012, now lapsed, which claims benefit to U.S. Provisional Application No. 60/395,308, filed on July 12, 2002 and U.S. Provisional Application No. 61/535,981, filed on October 17, 2011. Notably, the patent applicant, Mr. Spero handled the prosecution of the '551 Patent on his own in as a *pro-se* applicant as mentioned in, for example, the Reply to Non-Final Office Action dated August 13, 2017 and the Reply to Office Action dated June 23, 2015.

In the first non-final action, mailed on October 10, 2014, all claims 1-26 were rejected. Claim 4 was rejected under 35 U.S.C. §112, sixth paragraph. (Non-Final Office Action, dated October 10, 2014, pp. 2-5.) Claim 4 was also rejected under 35 U.S.C. §112, first paragraph, as failing to comply with the written description requirement. (Non-Final Office Action, dated October 10, 2014, pp. 5-6.) Claims 20 and 25 were rejected under 35 U.S.C. §112, second

paragraph, as being indefinite. (Non-Final Office Action, dated October 10, 2014, pp. 6-7.) Claims 1-3, 5-24 and 26 were rejected under 35 U.S.C. 102(b) as being anticipated by Spero et al, US 2004/0105264 ("Spero"). (Non-Final Office Action, dated October 10, 2014, pp. 7-17.) Claim 4 was rejected under 35 U.S.C. §103(a) as being unpatentable over Spero in view of Kiyohara et al, US 2006/0222213 ("Kiyohara"). (Non-Final Office Action, dated October 10, 2014, pp. 18-19.) Claim 25 was rejected under 35 U.S.C. §103(a) as being unpatentable over Spero in view of Savage et al, US 2004/0138726 ("Savage"). (Non-Final Office Action, dated October 10, 2014, pp. 19-20.)

A response was filed on January 12, 2015, but the claims were not entered pursuant to a Notice of Non-Compliant Amendment mailed January 15, 2015. A subsequent claim set was filed and entered on March 16, 2015, amending claims 16, 20 and 25. Claim 16 was amended to add the letter "n" to the word "and." (Amendment dated March 16, 2015, p. 6.) Claim 20 was amended to change "feeding information to a controller" to "transferring information to a controller," to change "a controller" to "where said controller," and to change "for adjusting" to "adjusts." (Amendment dated March 16, 2015, p. 6.) Claim 25 was amended to delete "SAD and other" and add "selected from the group consisting of seasonal affective disorder, sleep disorders, circadian rhythm disorders, delayed sleep phase syndrome, vitamin D deficiency and skin disorders" after "disorders" (previously modified by the now-deleted "SAD and other"). (Amendment dated March 16, 2015, p. 8.)

Another non-final action was mailed on June 23, 2015, in response to the Amendment dated March 16, 2015. Claim 7 was rejected/objected to for antecedent basis reasons under 35 U.S.C. §112. (Non-Final Office Action, dated June 23, 2015, p. 2.) Claims 1 and 3 were rejected under 35 U.S.C. §103(a) as being unpatentable over Morgan et al., US 2002/0047628 ("Morgan")

in view of Lys et al., US 2002/0047646 ("Lys"). (Non-Final Office Action, dated June 23, 2015, pp. 3-4.) Claim 2 was rejected under 35 U.S.C. §103(a) as being unpatentable over Morgan and Lys in view of Amerson et al., US 6,379,022 ("Amerson"). (Non-Final Office Action, dated June 23, 2015, p. 4-5.) Claim 4 was rejected under 35 U.S.C. §103(a) as being unpatentable over Morgan and Lys in view of Kinjo et al., US 2002/0046100 ("Kinjo"). (Non-Final Office Action, dated June 23, 2015, pp. 5-6.) Claim 5 was rejected under 35 U.S.C. §103(a) as being unpatentable over Morgan and Lys in view of Zampini et al., US 2008/0136356 ("Zampini") and Bolle et al., US 5,546,475 ("Bolle"). (Non-Final Office Action, dated June 23, 2015, pp. 6-8.)

Independent claim 6 was rejected under 35 U.S.C. §103(a) as being unpatentable over Morgan in view of Amerson. (Non-Final Office Action, dated June 23, 2015, pp. 8-9.) Claim 7 was rejected under 35 U.S.C. §103(a) as being unpatentable over Morgan and Amerson in view of Chang et al., US 2002/0039238. (Non-Final Office Action, dated June 23, 2015, pp. 9-10.)

Claims 8-17 were rejected under 35 U.S.C. §103(a) as being unpatentable over Morgan in view of Lys and further in view of Amerson. (Non-Final Office Action, dated June 23, 2015, pp. 10-18.) Claims 18-19 were rejected under 35 U.S.C. §103(a) as being unpatentable over Morgan in view of Lys in view of Amerson and further in view of Lemelson et al., US 5,983,161. (Non-Final Office Action, dated June 23, 2015, pp. 18-19.)

Claims 20-26 were rejected under 35 U.S.C. §103(a) as being unpatentable over Morgan in view of Lys. (Non-Final Office Action, dated June 23, 2015, pp. 20-25.) The Examiner found arguments with regards to claims 1-26 persuasive but entered new grounds of rejection as indicated hereinabove. (Non-Final Office Action, dated June 23, 2015, pp. 25-26.)

A response was filed on September 23, 2015. Claim 7 was amended to include the language "wherein one or more light sources are directional" in response to the pseudo-§112

rejection noting the antecedent basis issue as noted hereinabove. (Amendment dated September 23, 2015, p. 3.) No other amendment was made.

A final rejection was mailed on October 5, 2015. This rejection reiterated all the prior rejections of the Non-Final Action of June 23, 2015, as noted hereinbelow and cited hereinabove, with the exception of the pseudo-§112 rejection for antecedent basis of claim 7.

Claims 1 and 3 were rejected under 35 U.S.C.§103(a) as unpatentable over Morgan in view of Lys. (Final Office Action, dated October 5, 2015, pp. 2-4.) Claim 2 was rejected under 35 U.S.C. §103(a) as unpatentable over Morgan in view of Lys and further in view of Amerson. (Final Office Action, dated October 5, 2015, p. 4.) Claim 4 was rejected under 35 U.S.C. §103(a) as unpatentable over Morgan in view of Lys and further in view of Kinjo. (Final Office Action, dated October 5, 2015, pp. 5-6.) Claim 5 was rejected under 35 U.S.C. §103(a) as unpatentable over Morgan in view of Lys and further in view of Zampini and Bolle. (Final Office Action, dated October 5, 2015, pp. 6-7.)

Claim 6 was rejected under 35 U.S.C. §103(a) as unpatentable over Morgan in view of Amerson. (Final Office Action, dated October 5, 2015, pp. 7-8.) Claim 7 was rejected under 35 U.S.C. §103(a) as unpatentable over Morgan in view of Amerson and further in view of Chang and Lys. (Final Office Action, dated October 5, 2015, pp. 8-10.)

Claims 8-17 were rejected under 35 U.S.C. §103(a) as unpatentable over Morgan in view of Lys and further in view of Amerson. (Final Office Action, dated October 5, 2015, pp. 10-17.) Claims 18-19 were rejected under 35 U.S.C. §103(a) as being unpatentable over Morgan in view of Lys and further in view of Amerson and Lemelson. (Final Office Action, dated October 5, 2015, pp. 17-19.)

Claims 20-26 were rejected under 35 U.S.C. §103(a) as being unpatentable over Morgan in view of Lys. (Final Office Action, dated October 5, 2015, pp. 19-25.)

Applicant filed a response after final on February 5, 2016, including amendments to claims 1, 3, 5, and 6-8 and cancellation of claim 9. This response received an Advisory Action on Feb. 26, 2016, indicating non-entry of the Amendment.

Applicant thereinafter filed an RCE on May 26, 2016. The amendment included with the RCE amended claim 1 as follows: 1) Revision of "An illuminating device which produces light to meet an illumination requirement of an illuminated area…" to "A light fixture for illuminating an area to be lit capable of automatically meeting specific illumination requirements of difference sub-areas within the area to be lit…"; 2) Revision of "a light fixture including multiplicity of directional light sources, including at least two light sources pointing in different directions…" to "a multiplicity of independently controllable light sources, including at least two light sources of directional light output, such that each said source substantially illuminates a different sub-area within the area to be lit…"; and 3) Revision of "one or more detectors for sensing at least one of objects, surfaces and people within the illuminated area to be lit…" to "one or more detectors for sensing at least one of objects, surfaces and beings within the area to be lit including the specific sub-area location information…" (Amendment dated February 05, 2016, p. 2.)

Claim 3 was amended to change "wherein the controller taking into considerations the area…" to read "wherein the controller taking into considerations the intensity variations over the area…" (Amendment dated February 05, 2016, p. 3.)

Claim 5 was amended to change "detect an identity of one or more foods…" to "detect an identity of one or more foods in a sub-area." (Amendment dated February 05, 2016, p. 3.)

Claim 6 was amended to change "one or more cameras placed on the structure for detecting information…" to "one or more cameras placed on the structure for detecting coordinate-specific information…" (Amendment dated February 05, 2016, p. 4.)

Claim 7 indicated an amendment, but no amendment is apparent from the record. (Amendment dated February 05, 2016, p. 4.)

Claim 8 was amended to make the following changes: 1) Addition of "where different sub-areas of the illuminated area need to be illuminated at a different intensity and/or at a different spectrum than another sub-area of the illuminated area…" to the preamble; 2) Addition of "thereby illuminating different sub-areas of the illuminated area…" to the first limitation of the claim; Addition of 3) "according to best-practice standards" following "upon calculating the required illumination parameters…"; and 4) Addition of "that illuminates the specific sub-area…" following "the controller to adjust the directional light sources…" at the end of the claim. (Amendment dated February 05, 2016, p. 5.)

Claim 9 was cancelled and the remaining claims were renumbered and amended to adjust their dependency based on the renumbering. (Amendment dated February 05, 2016, pp. 5-8.) The Advisory Action also advised that this renumbering should not have occurred, although subsequent Examination appears to have relied on the renumbering. (*See*, e.g., Index of Claims dated August 15, 2016.)

Another Non-Final Rejection was issued on August 15, 2016. This rejection objected to claim 1 which was missing the word "and," to the use of "claim 20" in claims 20, 21 and 25, where "claim 19" should have been used, the use of "One" instead of "one" in claim 21, and the use of "claim 21" in claims 22-24, where "claim 20" should have been used. (Non-Final Office Action, dated August 15, 2016, p. 2.)

Claims 1-2, 5-7, 19 and 21-25 were rejected under 35 U.S.C. §102€ (e) as being anticipated by Kuhlman et al. 2012/0287493 ("Kuhlman"). (Non-Final Office Action, dated August 15, 2016, pp. 3-7.) Claims 8-18 were allowed, and claims 3-4 and 20-24 were indicated as being allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. (Non-Final Office Action, dated August 15, 2016, p. 7.)

An amendment was filed on January 16, 2017. The amendment amended claim 1 to add the word "and" as required by the Examiner. (Amendment dated January 16, 2017, p. 2.) The amendment further addressed the remaining numbering objections as noted above, without further substantive amendment to the claims. (Amendment dated January 16, 2017, pp. 7-8.)

A further Non-Final Rejection issued on May 1, 2017. One claim objection was noted, namely in claim 19, objecting to "a where said controller for adjusting adjusts" and indicating that this should be changed to "wherein said controller for adjusting…" (Non-Final Office Action, dated May 1, 2017, p. 2.) Objection was also made to the drawings as requiring a showing of "power and control device elements" as recited in claim 6. (Non-Final Office Action, dated May 1, 2017, p. 2.) Claims 19 and 25 were rejected under 35 U.S.C. §102(e) as being anticipated by Mueller et al., 2004/0052076 ("Mueller"). (Non-Final Office Action, dated May 1, 2017, pp. 3-5.) Claims 1-5 and 8-18 were indicated allowable. Claims 6-7 were indicated allowable subject to correction of the objection. Claims 20-24 were indicated as allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. (Non-Final Office Action, dated May 1, 2017, p. 5.)

An amendment was filed on August 1, 2017. The amendment amended claim 19 to correct the objection noted above, by changing "a where said controller for adjusting adjusts" to "wherein said controller for adjusting, adjusts…" (Amendment dated August 1, 2017, pp. 6-7.)

A Final Office Action was issued on August 11, 2017. An objection to the word "a" in line 6 of claim 19 was included. (Final Office Action, dated August 11, 2017, p. 2.) Claims 19 and 25 remained rejected under 35 U.S.C. §102(e) as being unpatentable over Mueller. (Final Office Action, dated August 11, 2017, pp. 2-5.) Claims 1-18 were indicated allowed, and claims 20-24 were indicated as allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. (Non-Final Office Action, dated May 1, 2017, p. 4.)

An Interview was held on November 13, 2017, as indicated by an Applicant-Initiated Interview Summary mailed on November 16, 2017. The summary indicated that a proposed amendment would overcome Mueller. (Interview Summary dated November 16, 2017.)

A Response After Final was filed on November 13, 2017, the same day as the Interview above. The response amended claim 19 to: 1) Change the preamble from "an automated irradiating device for providing radiation to individuals within an area, intended to provide a desired radiation in a sub-area proximate to the individuals, comprising…" to "an automated irradiating device for providing a desired radiation to individuals within an area, comprising…"; 2) Change "an irradiation fixture including one or more directional radiation sources where the radiation is in a defined direction" to "at least two substantially directional heat radiation sources pointing in different directions"; 3) Change "feeding transferring" to "transferring"; 4) Strike an occurrence of "a," "(i)," and "(ii)"; and 5) Add "the automated irradiating device further comprising one detector being a camera with capability for transferring data to the processor arranged with image recognition algorithms for sensing any of the information selected from the list comprised of: a presence, an identity, a location, a position, an activity, and a body temperature of an individual; the controller having processing capability for using the information and determining the heating requirements of the individuals from at least one of (i) algorithms to calculate radiation parameters,

(ii) stored data of heating practices, and (iii) the identified individual's stored personal preferences;…"

A Notice of Allowance was mailed on December 19, 2017 and the Issue Fee was paid on March 18, 2018.

B. Summary of the '551 Patent

The '551 Patent, entitled "Detector Controlled Illuminating System," issued on April 24, 2018 to inventor Yechezkal Evan Spero and is unassigned. The application which led to the '551 Patent was filed on January 24, 2012, with a priority date of July 12, 2002. (Ex. PAT-A; Ex. OTH-A at ¶39.)

In contrast to the Stam '573 Family of Patents, the Spero '551 Patent introduced a system "built around a 'digital' light source":

> **The system is built around a "digital" light source**. That is, the emanating lighting effect is the sum of the characteristics of a multiplicity of discretely controllable "digit" sources. **The difference between the individual 'digit' light sources and their summation manifests itself in the resultant light characteristic**, be in its intensity, spatial intensity distribution, spectral energy content and spectral intensity distribution. All of these characteristics are also variable with time.

(Ex. PAT-A at 16:39-46, emphasis added; Ex. OTH-A at ¶39.)

The '551 Patent discloses numerous flexible applications for this digital light source, centered around the "controllability offered by breaking the light output up into discrete specifically aimable and dimmable elements," which can be addressed by control electronics to effect intensity, spectrum and distribution." (Ex. PAT-A at 24:37-47; Ex. OTH-A at ¶41.) For headlights, the disclosures identify yet another level of control:

[t]he flexible characteristics of the DLF [digital lighting fixture] allow for spatial

variations of the intensity and spectral power distribution of the light over the area covered. When the element of variation of intensity and SPD [spectral power distribution] with time over the area covered is introduced another dimension of flexibility is introduced. These properties are unique to the DLF and allow them to deal with dynamic lighting situations in a way not afforded by prior-art lighting devices.

(Ex. PAT-A at 57:24-37; Ex. OTH-A at ¶41.)

The '551 Patent further explains how the "digital aspect" of the illuminating devices gives rise to "control capability" for individual LEDs or selectable groups of LEDs:

> The multiple light sources of specific characteristics provide quanta of power and spectrum which are smoothly added or detracted to generate a changed lighting effect. The digital aspect arises from the sufficient progression of values, varying by minutes to produce a continuum so as to be non-discernable or irrelevant to the user. The added controllability is realized by **breaking up the light-production, into discrete, specifically aimable, and dimmable elements** which can be addressed by control electronics for the purpose of affecting the intensity, spectrum and spatial distribution of spectrum and of intensity of the illumination provided by the luminaire of the present invention.
>
> The overall combination of control capability and discrete light sources yields a digital lighting fixture. The terminology "digital" as used herein refers to the discrete nature of the multiple LED lamps provided in the luminaire, whereby "digital" control results from the individual control of the discrete, i.e. 'digital' lighting elements, the LEDs, in the luminaire.

(Ex. PAT-A at 2:51-3:3, emphasis added.)

The '551 Patent also teaches how various applications can obtain a synergistic effect from the controllability offered by "discrete specifically aimable and dimmable elements" and image detection "devices capable of detection changes in the surrounding environment" "so as to provide

the optimal lighting solution in real-time." (Ex. PAT-A at 57:32-37; Ex. OTH-A at ¶43.) By way of example, the '551 Patent discloses:

> Adaptive Frontal-lighting Systems which aid in seeing around curves and other features in the road. In these systems the light distribution pattern and color spectrum will be changed according to the instantaneous road conditions at hand. Thus, the headlamp now has much more flexibility than the high beam/low beam variation of today.

(Ex. PAT-A at 51:43-49; Ex. OTH-A at ¶43.)

More particularly, the '551 Patent teaches how "[a]nalysis by a detector or an imaging system of the oncoming vehicles [*sic*] position (using its headlights for example) can be used to determine which exact aiming is the maximum allowable for any given traffic situation and road layout." (Ex. PAT-A at 52:62-65.)

The '551 Patent further discloses glare-free adaptive driving beam systems:

> [u]sing color and pattern recognition techniques it is possible to determine what is a sign. It is then possible to provide the equivalent of "task lighting" and use the controller and properly aimed SLS [solid state light source, e.g. LED] to follow and illuminate distant overhead and roadside signs for a longer time, yet not blind oncoming traffic due to the narrow beam.

(Ex. PAT-A at 52:66 – 53:4.)

These teachings are reflected in base claim 6 and the new reexamination claims, claims 24-87. *See*, claim 6 and claims 24, 32 and 56 below, which are representative of the new reexamination claims. The full set reexamination claims can be found at Ex. OTH-C, New Claims.

6. An illuminating device having automatic control of the light provided to an illuminated area comprising:

a structure for incorporating illuminating device elements;

one or more light sources incorporated in the structure and in communication with a power source;

electronic circuitry apparatus for the controlled powering of the light source and other illuminating device elements; one or more cameras placed on the structure for detecting coordinate-specific information about the illuminated area, said camera in communication with power and control device elements;

a controller integrated with the structure, in communication with the light source controlling power circuitry, said controller arranged to processes the information communicated from the camera and automatically control the light provided to the illuminated area.

24. An illuminating device having automatic control of light provided to an illuminated area comprising:

a structure for incorporating illuminating device elements, wherein the structure comprises a motor vehicle;

a plurality of individually controllable LEDs incorporated in the structure via at least one headlamp mounted to the structure, each headlamp including at least one of the LEDs, the LEDs in communication with a power source;

electronic circuitry apparatus for the controlled powering of the LEDs and other of the illuminating device elements;

one or more processors;

one or more sensors, including one or more cameras, placed on the structure for detecting coordinate-specific information about the illuminated area, at least one of said cameras in communication with power, and in communication with at least one of the one or more processors;

a controller, including at least one of the one or more processors, integrated with the structure via mounting, in communication with the LED controlling power electronic circuitry apparatus, said controller arranged to process the information communicated from the cameras and to automatically control the light provided to the illuminated area; and

memory storing instructions that, when executed by one or more processors of the controller, enable the controller to:

determine first coordinates corresponding to an other vehicle, based on the coordinate-specific information;

select a cluster of the LEDs that emit light toward at least a portion of the other vehicle based on the LEDs having emission aimings associated with the first coordinates; and

change emission of the selected cluster of LEDs relative to emission of other LEDs not included in the cluster to create headlamp illumination that preserves a first level of illumination illuminating past the other vehicle while preventing glare to a driver of the other vehicle.

32. An illuminating device having automatic control of light provided to an illuminated area comprising:

a structure for incorporating illuminating device elements, wherein the structure comprises a motor vehicle;

a plurality of individually controllable LEDs incorporated in the structure via at least one headlamp mounted to the structure, each headlamp including at least one of the LEDs, the LEDs in communication with a power source;

electronic circuitry apparatus for the controlled powering of the LEDs and other of the illuminating device elements;

one or more processors;

one or more sensors, including one or more cameras, placed on the structure for detecting coordinate-specific information about the illuminated area and positioned to capture an image of at least one target, at least one of said cameras in communication with power, and in communication with at least one of the one or more processors;

a controller, including at least one of the one or more processors, integrated with the structure via mounting, in communication with the LED controlling power electronic circuitry apparatus, said controller arranged to process the information communicated from the cameras and to automatically control the light provided to the illuminated area; and

memory storing instructions that, when executed by one or more processors of the controller, enable the controller to:

create a beam of diminished illumination illuminating at least a portion of the at least one target with non-glaring illumination, created within a broader field of illumination having

different intensity than the beam, by one or more changes to characteristics of first light of a cluster of the LEDs providing the first light directed at the at least a portion and creating the beam, the beam diminished in intensity relative to the broader field of illumination illuminating at least above and on both sides of the beam; and

follow, based at least in part on data from one or more of the cameras, the at least one target with the diminished illumination as the at least one target changes location relative to the motor vehicle.

56. An illuminating device having automatic control of light provided to an illuminated area comprising:

a structure for incorporating illuminating device elements, wherein the structure comprises a motor vehicle;

a plurality of individually controllable LEDs incorporated in the structure via at least one headlamp mounted to the structure, each headlamp including at least one of the LEDs, the LEDs in communication with a power source;

electronic circuitry apparatus for the controlled powering of the LEDs and other of the illuminating device elements;

one or more processors;

one or more sensors, including one or more cameras, placed on the structure for detecting coordinate-specific information about the illuminated area and positioned to capture an image of at least one other vehicle ahead of the motor vehicle, at least one of said cameras in communication with power, and in communication with at least one of the one or more processors;

a controller, including at least one of the one or more processors, integrated with the structure via mounting, in communication with the LED controlling power electronic circuitry apparatus, said controller arranged to process the information communicated from the cameras and to automatically control the light provided to the illuminated area; and

memory storing instructions that, when executed by one or more processors of the controller, enable the controller to:

determine, based on data from one or more of the sensors, a vertical and horizontal position associated with the at least one other vehicle;

select a first cluster of the LEDs based at least in part on at least one of the vertical and horizontal position compared to known aimings of light associated with the first cluster; and reduce intensity of illumination to non-glaring illumination of a first area associated with the at least one other vehicle, relative to intensity of illumination on both sides of the first area at elevations common with the first area illuminated by a second cluster of the LEDs, by control of emission from the first cluster.

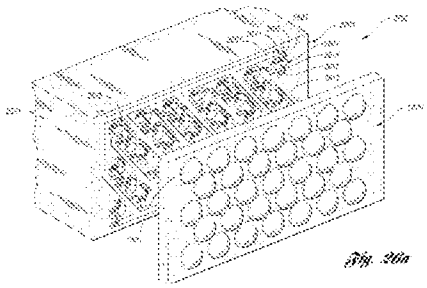
VII. 37 C.F.R. §1.510(b)(1): Statement Establishing Substantial New Question of Patentability ("SNQ") of Claim 6 of the '551 Patent

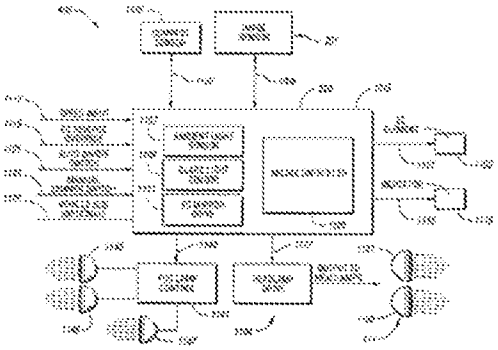
A. The Stam PCT and Harbers Combination Fails to Teach Numerous Limitations

The combination of Stam PCT and Harbers raises a substantial new question of patentability, as neither prior art reference was previously considered in the underlying prosecution of the '551 Patent. While Patent Owner and inventor Mr. Spero, a *pro se* patent applicant, identified Stam '632 in the specification, neither Stam PCT nor Harbers were considered in the underlying prosecution of the '551 Patent, let alone the combination of the two references. Furthermore, the disclosures of Stam PCT and Harbers are not cumulative to information considered by the examiner during prosecution of the '551 Patent. Notably, the Stam PCT disclosure includes different subject matter than the Stam '632, in particular with respect to the relevant LED embodiments.

As seen in the table below, claim 6 includes several limitations in common with the teachings disclosed in Stam PCT and Harbers such that a reasonable examiner would consider the teachings of Stam PCT and Harbers to be important in the consideration of patentability. However, it is the position of the Patent Owner that while the combination of teachings from Stam PCT and Harbers raises a substantial new question of patentability, these references does not render claim 6 unpatentable.

Claim 6 (original)	Stam PCT and Harbers
6. *An illuminating device having automatic control of the light provided to an illuminated area comprising:*	Stam PCT- "A system and method of automatically controlling exterior vehicle lights … to maximize the illuminated area in front of the vehicle." (Ex. PA-A at Abstract)
a structure for incorporating illuminating device elements;	Stam PCT- "The present invention pertains to control systems for controlling the exterior lights of a vehicle and components that can be used with such a control system." (Ex. PA-A at 1.) "As noted above, such exterior lights may include headlamps, tail lights, foul weather lights such as fog lights, brake lights, center-mounted stop lights (CHMSLs), turn signals, back-up lights, cargo lights, puddle lights, license plate illuminators, etc." (*Id.* at 10.) *See* Fig. 1. Harbers- "The invention relates to a vehicle headlamp comprising a light source which includes a plurality of opto-electronic elements. The invention also relates to a vehicle provided with a headlamp." (Ex. PA-B at 1:10-15.)
one or more light sources incorporated in the structure and in communication with a power source;	Stam PCT- "LED headlamp 2600 includes a heat extraction member 2601 that serves as a support for mounting semiconductor optical radiation emitters 2603, 2605. Where the semiconductor optical radiation emitters 2603, 2605 are electrically connected to the heat extraction member, the heat extraction member provides an electrical connection to the semiconductor optical radiation emitters . . . during operation." (Ex. PA-A at 74.) *See* Figs. 26a and 26b. Harbers- "The use of a plurality of opto-electronic elements with a relatively high luminous flux enables a vehicle headlamp to be manufactured having much more dynamic lighting possibilities than the known vehicle headlamp. The opto-electronic elements can be switched on and switched off, with the spatial distribution of the generated light beam depending on the conditions." (Ex. PA-B at 2:6-12.)

Claim 6 (original)	Stam PCT and Harbers
electronic circuitry apparatus for the controlled powering of the light source and other illuminating device elements;	Harbers- The use of a plurality of opto-electronic elements [LEDs] with a relatively high luminous flux enables a vehicle headlamp to be manufactured having much more dynamic lighting possibilities than the known vehicle headlamp. (Ex. PA-B at 2:6-9.) The ordering, providing and selectively switching on and off of opto-electronic elements… in the form of an array may also be considered as an invention itself. (*Id.* at 7:20-21.)
one or more cameras placed on the structure for detecting coordinate-specific information about the illuminated area, said camera in communication with power and control device elements;	Stam PCT- "The control system comprises an image array sensor including a plurality of pixels, an optical system configured to image the scene forward of the controlled vehicle onto the image array sensor, the optical system including a forwardmost surface, and a control circuit for processing the image of the scene obtained from the image array sensor and for controlling the exterior lights in response to objects detected in the processed scene." (Ex. PA-A at 2-3.) 
a controller integrated with the structure, in communication with the light source controlling power circuitry, said controller arranged to processes* [sp] *the information communicated from the camera and automatically control the light provided to the illuminated area.	Stam PCT- A system and method of automatically controlling exterior vehicle lights includes an image sensor (201) and a controller (1105) to general control signals. The control signals are derived on information obtained from the image sensor as well as other detected parameters pertaining to the detected light source(s), the vehicle having the inventive control system, and the ambient environment. (Ex. PA-A at Abstract.) The control system comprises an image array sensor including a plurality of pixels, an optical system configured to image the scene forward of the controlled vehicle onto the image array sensor, the optical system including a forwardmost surface, and a control circuit for processing the image of the scene obtained from the

Claim 6 (original)	Stam PCT and Harbers
	image array sensor and for controlling the exterior lights in response to objects detected in the processed scene. (Ex. PA-A at 5.) *See* Fig. 11  Harbers- the "spatial distribution of the light beam generated by the light source is continuously adjustable…Preferably, the spatial distribution is influenced by the speed of the vehicle, the rotational position of the steering wheel of the vehicle, the weather conditions, and it can also be influenced by the driver." (Ex. PA-B at Abstract, numerical identifiers omitted.)

Below, relevant limitations of claim 6 will be reviewed in the context of the combination of Stam PCT and Harbers to establish that the claim is patentable. As the arguments presented below are not exhaustive of the applicable patentability grounds, Patent Owner reserves its right to present further arguments to the extent necessary.

6. ***An illuminating device having automatic control of the light provided to an illuminated area comprising:***

… ***a structure for incorporating illuminating device elements;***

According to the abstract, Stam PCT is directed to a "system and a method of automatically controlling exterior vehicle lights that includes an image sensor (201) and a controller (1105) to generate control signals." (Ex. PA-A at 1.) As depicted in Figure 1, Stam PCT discloses illuminating device elements, e.g., exterior vehicle lights positioned on a vehicle. (Ex. PA-A at 120.)

Likewise, in Harbers the "invention relates to a vehicle headlamp comprising a light source which includes a plurality of opto-electronic elements. The invention also relates to a vehicle provided with a headlamp." (Ex. PA-B at 1:10-15.)

... ***one or more light sources incorporated in the structure and in communication with a power source;***

According to the proffered construction detailed in Section III, the claim term *light source* means an individual LED; Figures 26a and 26b of Stam PCT depict individual LEDs incorporated in the vehicle headlamp. (Ex. OTH-A at ¶54.) More specifically, the specification of Stam PCT links the LEDs to a power source:

> LED headlamp 2600 includes a heat extraction member 2601 that serves as a support for mounting semiconductor optical radiation emitters 2603, 2605. Where the semiconductor optical radiation emitters 2603, 2605 are electrically connected to the heat extraction member, the heat extraction member provides an electrical connection to the semiconductor optical radiation emitters . . . during operation.

(Ex. PA-A at 74.)

Harbers also discloses individual LEDs incorporated in the vehicle headlamp, *in communication with a power source*:

> The use of a plurality of opto-electronic elements with a relatively high luminous flux enables a vehicle headlamp to be manufactured having much more dynamic lighting possibilities than the known vehicle headlamp. The opto-electronic

elements can be switched on and switched off, with the spatial distribution of the generated light beam depending on the conditions.

(Ex. PA-B at 2:6-11, emphasis added; Ex. OTH-A at ¶64.)

… ***electronic circuitry apparatus for the controlled powering of the light source and other illuminating device elements;***

This claim limitation is missing in the primary Stam PCT reference but disclosed in the Harbers reference. However, as established below, absent hindsight bias, there is no motivation to combine the two references. (Ex. OTH-A at ¶90.)

The primary inventor of Stam PCT, Joseph S. Stam, makes it clear in his declaration that though Stam PCT discloses two limited LED applications for headlamps, "[i]n all cases, the LEDs in each array were connected together and operated by a single controller, such that the entire array would be on/off or dimmed, as shown in Fig. 26a." (Ex. PA-A at pp. 77-79; Ex. OTH-A at ¶53.) Accordingly, under the proper construction of light source detailed in Section III, the two limited LED embodiments in Stam PCT do not disclose *controlled powering of the* [individual LED] *light source*. (Ex. OTH-A at ¶75.)

In his declaration, Stam explains that the embodiments in Stam PCT were primarily directed to halogen/HID light sources, with the exception of two limited LED embodiments, and underscores why in Stam PCT "the light source is treated as a fixed block of light—whether halogen/HID or an LED array— that can be 'steered' up/down or right/left, treating an array of LEDs as a unit that would be operated together" and "thus not individually controlled or capable of facilitating control to selectable groups of LED chips." (Ex. OTH-A at ¶¶49-55, 73.)

The Stam declaration provides context for the state of LED headlamp applications and how that impacted the prevailing view at the time, as reflected in the Stam PCT: "[i]n view of the

technical constraints that limited LED usage in headlights in 2001-2002, we limited our use of LED applications to two applications—headlamp steering and flashing":

> It has long been considered to be desirable to provide headlamps that can be steered in the direction that the vehicle is turning. It is also desirable to provide forward lighting that can be turned OFF, or substantially attenuated, for such a short period of time that the driver does not notice that the lights are OFF. In this way, reflections do not exist during image acquisition. Although a light emitting diode (LED) lamp can be used to provide these features in a cost-effective manner, LED lamps producing enough light to implement a vehicle headlamp are not commercially available. LEDs suffer from a number of disadvantages that limit their application in vehicle headlamps, not the least of which are the relatively small amounts of light produced by LEDs and manufacturability limitations when incorporating LEDS having exotic constructions. Because of these disadvantages, LED lamps have not been used to implement a vehicle headlamp despite the fact that LEDs are more rugged, more energy efficient, and significantly longer lasting than other light technologies. Additionally, means of producing white light from LEDS have only recently become practical as discussed in U.S. Patent No. 5,803,579, entitled ILLUMINATOR ASSEMBLY INCORPORATING LIGHT EMITTING DIODES, issued to John K. Roberts et al. on September 8, 1998.

(Ex. PA-A at 72-73, emphasis added; Ex. OTH-A at ¶50.)

As Stam provides in his declaration "[i]n view of the LED constraints at the time, the Stam PCT disclosure is limited to two LED applications that could be used as a complement to and/or as a substitute for halogen/HID light sources, to address specific imaging challenges and improve auto high beam functionality." (Ex. PA-A at 72-79; Ex. OTH-A at ¶51.)

> The Stam declaration explains the two LED applications disclosed in the Stam PCT:
>
> One of these LED applications focuses on the problem of flashing, which occurs when reflections off an object, such as a sign, are misinterpreted by the image sensor as an oncoming vehicle and trigger disruptive, rapid high/low beam flashing

(repeatedly turning high beams on and off). As one solution for headlamp flashing, we contemplated the use of LEDS to rapidly reduce the light levels or turn the LEDS off, during an image-sampling interval, so that the reflections do not exist or interfere with image acquisition and processing. If done fast enough, the driver would not notice the change in light levels and the problem of flashing would be rectified. Such rapid reduction of intensity would be difficult or impossible with halogen/HID light sources.

The second LED application focused on an improved way to "steer" the light source by replacing the halogen/HID light with an LED array that could be aimed at a fixed angle for auto high beam applications. To facilitate "steering" for auto high beam applications, we disclosed use of an LED array to 1) help provide sufficient output light and 2) project light in more than one either horizontal (*see* Fig. 27) or vertical direction (*see* Fig. 28) by providing a support member with two different angled orientations. In all cases, the LED arrays were connected together and operated by a single controller, such that the entire array would be on/off or dimmed, as shown in Fig. 26a.

(Ex. PA-A at 73-79; Ex. OTH-A at ¶¶52-53.)

In his declaration, Stam provides a detailed analysis of Figures 26a and 26b, to establish that Stam PCT fails to disclose controlled powering of individual LEDs or a selectable group of LEDs:

More specifically, in Fig. 26a, every optical radiation emitter (LED chip) 2603 is electrically connected together "to electrical conductor strip 2607 through a wire bond 2609 and a resistor 2611. Each of the emitters 2605 is connected to electrical conductor strip 2613 through a bonding wire 2615 and a resistor 2617." (*Id.* at p. 74.) **Since electrical conductor strips 2607, 2613 are shown to be common to multiple LED chips, they necessarily are not individually controlled or capable of facilitating control to selectable groups of LEDs**.

(Ex. OTH-A at ¶54, emphasis added.)

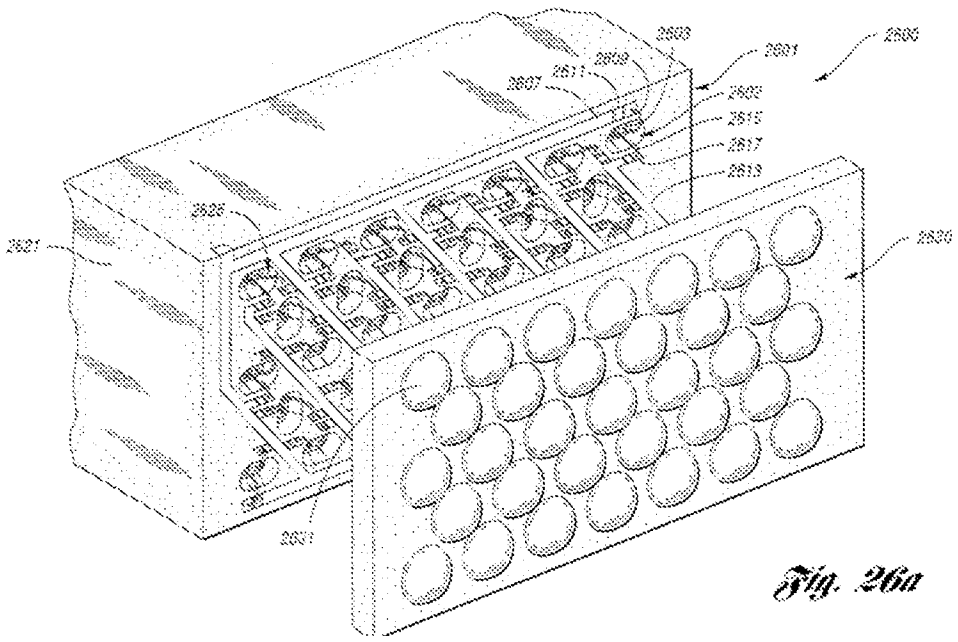


Fig. 26a

While Stam PCT provides power and control functionality to the LED array as a fixed unit, it fails to provide *controlled powering of the* [individual LED] *light source*. (Ex. OTH-A at ¶75.) Figs. 50a-50c of the Stam PCT, further illustrate the types of illumination beam patterns that can be produced from the disclosed auto high beam applications. (Ex. OTH-A at ¶55.) Regarding Figs. 50a-50c, as Stam notes, "[iI]n each case, the light source is treated as a fixed block of light—whether halogen/HID or an LED array— that can be 'steered' up/down or right/left by varying the power to the LED array—treating an array of LEDs as a unit that would be operated together." (Ex. OTH-A at ¶55.)

Another headlamp configuration is depicted in Fig. 28, in which two LED arrays are provided, one for low and high beams—here again, each array is treated as a single unit to be operated together:

> [a]nother alternative design for a headlamp for providing low and high beams is illustrated in Fig. 28. The headlamp 2800 includes a heat extraction member 2801

having two lamp sections 2803 and 2805. The heat extraction member 2801 is configured to include the two lamp sections 2803 and 2805, each of which is substantially identical to lamp 2601 [in Fig. 26a]. The heat extraction member provides two front faces at an angle of 1° to 2°, and may advantageously be angled at approximately 1.5°. The angle is exaggerated in Fig. 28 so that the angled surfaces are readily visible.

(Ex. PA-A at 79, emphasis added; Ex. OTH-A at ¶56.)

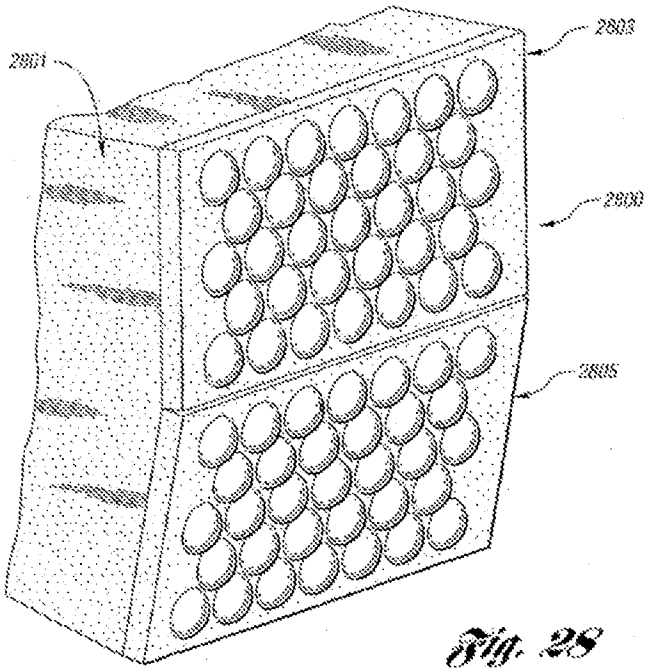


Fig. 28

In his declaration, Stam also provides context for a specification statement in reference to Fig. 28 and the two separate LED lamp sections, 2803 and 2805 for high and low beams – "[b]y controlling the selection of the LEDs that are illuminated, the headlamps can be aimed" (Ex. PA-A at 79)—which Stam states, "when read in context, is consistent with the Stam PCT teaching that one or more LED arrays can be controlled as a single unit and in that capacity, steered and aimed." (Ex. OTH-A at ¶57.) Similarly, Stam clarifies that the specification sentence – "[t]he circuit traces disclosed in Fig. 26a illustrate a pattern that may be used where separate supply is provided for the

different emitters" (Ex. PA-A at 77.)"discloses the use of separate color emitters, for the purpose of creating white light and thus requires separate supplies for the different color emitters, but does not teach the ability to individually control an LED chip or selectable clusters of LED chips." (Ex. OTH-A at ¶74.)

Finally, in his declaration, Stam acknowledges that

> It was not until US Patent No. 6,861,809 which was filed on September 5, 2002 and published on June 12, 2003 that we first described the use of individually controllable LEDs where a portion of the LEDs within an array could be dimmed or turned off to avoid glaring an oncoming vehicle.

(Ex. PA-E; Ex. OTH-A at ¶61.)

See Fig. 7b and the accompanying description: "[a]lternatively, the window 700 may contain several independently controlled blocks 702 as shown in Fig. 7B. There may be any number of blocks, depending on the granularity of control that is desired. By selectively darkening these blocks, almost any desired beam pattern can be achieved." (Ex. PA-E at 13:6-14:3, emphasis added; Ex. OTH-A at ¶61.)

Thus, for the reasons set forth above, Stam PCT fails to teach the limitation *electronic circuitry apparatus for the controlled powering of the light source.* (Ex. OTH-A at ¶75.)

By contrast, the Harbers reference teaches "[t]he use of a plurality of opto-electronic elements [LED] with a relatively high luminous flux enables a vehicle headlamp to be manufactured having much more dynamic lighting possibilities than the known vehicle headlamp." (Ex. PA-B at 2:6-9; Ex. OTH-A at ¶64.) Harbers further provides: "[t]he ordering, providing and selectively switching on and off of opto-electronic elements… in the form of an array may also be considered as an invention itself. (Ex. PA-B at 7:20-21.) Accordingly, Harbers discloses the *electronic circuitry apparatus for the controlled powering of the light source*

limitation. (Ex. OTH-A at ¶81.) However, as disclosed in detail below, absent hindsight bias, there is no motivation to combine Stam PCT with Harbers.

> … ***one or more cameras placed on the structure for detecting coordinate-specific information about the illuminated area, said camera in communication with power and control device elements;***

As depicted in Fig. 26a, Stam PCT teaches "an image array sensor including a plurality of pixels, an optical system configured to image the scene forward of the controlled vehicle onto the image array sensor, the optical system including a forwardmost surface, and a control circuit for processing the image of the scene obtained from the image array sensor and for controlling the exterior lights in response to objects detected in the processed scene." (Ex. PA-A at 2-3.)

By contrast, Harbers doesn't disclose *a camera for detecting coordinate-specific information about the illuminated area, said camera in communication with power and device control elements*. (Ex. PA-B.) Although Harbers discloses "ordering, providing and selectively switching on and off opto-electronic elements . . . in the form of an array" in response to the velocity of the vehicle, rotational position of the steering wheel, bad weather or in dimly-lit areas (Ex. PA-B at 7:11-22), it lacks a camera or sensor, in communication with power and control device and is thus incapable of *detecting coordinate-specific information about the illuminated area*. (Ex. OTH-A at ¶¶82-83.)

> … ***a controller integrated with the structure, in communication with the light source controlling power circuitry, said controller arranged to processes the information communicated from the camera and automatically control the light provided to the illuminated area;***

Neither Stam PCT nor Harbers teach this limitation.

Stam PCT fails to teach a controller, *in communication with the light source controlling*

power circuity, wherein the controller is *arranged to processes* [*sic*] *the information communicated from the camera and automatically control the light provided to the illuminated area.* As detailed above, in Stam PCT, LEDs are not individually controlled or capable of facilitating control to selectable groups of LEDs and thus the controller in Stam PCT is not *in communication with the light source [individual LED] controlling power circuitry* and 2) not *arranged to processes* [*sic*] *the [coordinate-specific] information communicated from the camera and automatically control the light provided to the illuminated area.* (Ex. OTH-A at ¶¶76-77.) Stated differently, because there is no mechanism for controlled power of individual LEDs in Stam PCT, the controller cannot be *in communication with the light source controlling power circuitry* and thus cannot be *arranged to processes* [*sic*] *the* [coordinate-specific] *information from the camera to automatically control the light provided to the illuminated area. Id.*

Likewise, Harbers doesn't teach *a controller arranged to process the information communicated from the camera and automatically controlling the light provided to the illuminated area.* (Ex. OTH-A at ¶¶82-84.) Harbers does not disclose a camera, let alone a camera *for detecting coordinate-specific information about the illuminated area* and thus doesn't correlate automatic control of the light based on *information communicated from the camera.* (*Id.*) Harbers discloses automatic adjustments in relation to vehicle velocity and steering wheel position, not dynamic adjustments *based on* [coordinate-specific] *information communicated from the camera.* (Ex. OTH-A at ¶83.)

B. No Motivation to Combine

In addition to the deficiencies that arise when mapping claim 6 to the Stam PCT and Harbers combination, there is no motivation to combine the asserted references. (Ex. OTH-A at ¶¶79, 84, 86-88.) First, the combination of Stam PCT and Harbers changes the principle of operation of Harbers. (Ex. OTH-A at ¶90.) Though Harbers provides light that can continuously

adjust, those adjustments are limited to a set of defined vehicle inputs such as vehicle speed or steering wheel position and/or manual adjustments. (*Id.*) Harbers does not provide any set of operations that includes a camera or *a controller arranged to process the information communicated from the camera, to automatically control the light provided to the illuminated area*. (*Id.*) As Stam states in his declaration, "[a]ny hypothetical combination of the teachings of Stam PCT and Harbers would require a substantial reconstruction and redesign of the elements shown in Harbers as well as a fundamental change in its basic principles of operation":

> Notably, in 2000, when Harbers was filed, although camera-based image detection systems were disclosed, Harbers did not describe or suggest that their system did or could include any such LED-to-image detection correlation. Moreover, while the problem of headlamp glare was well known in 2000, the Harbers system is not directed to that problem. Accordingly, any combination of Stam PCT and Harbers, requires that the principle of operation in Harbers undergo a substantial change. For these reasons, absent hindsight bias, a POSITA in 2002 would have no motivation to combine Stam PCT and Harbers.

(Ex. OTH-A at ¶¶90-91.)

C. Teaching Away

Second, when viewed as a whole, Stam PCT includes statements that teach away from a headlamp with individually controlled LEDs, as required by the claims. (Ex. OTH-A at ¶¶92-94.) Stam PCT includes the following "teaching away": "**LEDs suffer from a number of disadvantages that limit their application in vehicle headlamps**, not the least of which are [1] the relatively small amounts of light produced by LEDs and [2] manufacturability limitations when incorporating LEDS having exotic constructions. **Because of these disadvantages, LED lamps have not been used to implement a vehicle headlamp**. . . Additionally, means of producing white light from LEDS have only recently become practical." (Ex. PA-A at 74, emphasis added.) In his

declaration, Stam expressly provides:

> [i]t is my position that given the clear statements in Stam PCT regarding the constraints and technical issues surrounding use of LEDs for headlights, during the 2002-2003 time frame, a POSITA would be discouraged from using individually controlled LEDs or otherwise expanding usage of LEDS in headlights beyond the two limited applications of LED arrays expressly disclosed.

(Ex. OTH-A at ¶94.)

D. Contemporaneous filings establish relevant mindset

Third, as evidenced by contemporaneous prior art filings in 2002, those skilled in the art of auto headlight design, needed to rely on proven technologies—e.g., halogen and xenon applications. (Ex. OTH-A at ¶95.) At that time, LED technology was not viewed as suitable for headlamp applications. (*Id.)* As Stam lays out in his declaration, from 2000-2003, the fields of LED lighting and image sensing were "emerging technologies, each under development for distinct product offerings" and were "as a matter of course, separate and distinct." (*Id.* at ¶96.) But for a working relationship between a member of the LED lighting product team and a member of the image sensing product team, that "forged a unique opportunity for interdisciplinary engagement and collaboration" at Gentex, and spurred the '573 Family of Patents, Stam states that to the best of his knowledge, "it would not have been obvious for a POSITA in 2002-2003 to combine coordinate-specific image detection technology with any LED functionality." (Ex. OTH-A at ¶¶95-96.)

Thus, when viewed in the context of the relevant 2002-2003 time frame, a POSITA would lack motivation to combine teachings from Stam PCT and Harbers in the manner claimed, for the following reasons: 1) Stam PCT teaches away from use of individually controlled LEDs as recited in the claimed invention; 2) any hypothetical combination is inconsistent with the principle of

operation of Harbers and thus a by-product of hindsight bias; and 3) during the relevant time, the evolving fields of LED technology and image detection were wholly separate fields. (Ex. OTH-A at ¶¶90-97.) Finally, as detailed in Section XI, objective indicia further support nonobviousness.

VIII. Support for New Claims

Please see Exhibit OTH-D for Support for New Amendments. For ease of review, OTH-D illustrates new claims 24-87 in redlined form in view of base claim 6.

IX. New Claims 24-87 are Patentably Distinct over The Combination of Stam PCT and Harbers

As new claims 24-87 narrow the scope of base claim 6, the nonobvious arguments presented in Section VIII, apply with equal force to the newly presented claims. The narrowing amendments made in claims 24-87 present additional points of distinction with respect to the Stam PCT and Harbers combination.

Stam PCT and Harbers fail to teach or suggest many of the features recited in new claims 24-87 over base claim 6. Looking first at each asserted reference individually, Stam PCT fails to teach the following limitations in all new claims specifically 1) controlling individual LEDs responsive to coordinate-specific image detection data, based on known aimings or coordinates of those LEDs and 2) a control strategy that correlates individual LED controls to coordinate-specific sensor data of an object/target to diminish/enhance illumination of a coordinate-specific region. (Ex. OTH-F, Side-by-Side independent claim comparison; Ex. OTH-A at ¶¶77-79.)

As a result, Stam PCT does not teach or suggest controlling an individual LED or group of LEDs within an array, responsive to coordinate-specific image detection data, so that the controller 1) per claim 6, is *arranged to processes* [*sic*] *the [coordinate-specific] information communicated from the camera and automatically control the light provided to the illuminated area*; 2) per new claim 24 can *change emission of the selected cluster of LEDs relative to emission of other LEDs*

not included in the cluster to create headlamp illumination that preserves a first level of illumination illuminating past the other vehicle while preventing glare to a driver of the other vehicle; 2) per new claim 32, *follow, based at least in part on data from one or more of the cameras, the at least one target with the diminished illumination as the at least one target changes location relative to the motor vehicle;* and 3) per new claim 56, *select a first cluster of the LEDs based at least in part on at least one of the vertical and horizontal position compared to known aimings of light associated with the first cluster; and reduce intensity of illumination to non-glaring illumination of a first area associated with the at least one other vehicle, relative to intensity of illumination on both sides of the first area at elevations common with the first area illuminated by a second cluster of the LEDs, by control of emission from the first cluster*. (Ex. OTH-F; Ex. OTH-A at ¶78.)

In sum, Stam PCT fails to optimize lighting patterns to match the particular road scene. (Ex. OTH-A at ¶79.) By treating light as a fixed block, in the presence of objects/targets, high beams—which output significantly brighter light and enhance safety— are shifted away from the road scene rather than individually controlled at a coordinate-specific level to provide optimized, non-glaring lighting patterns. (*Id.)*

Accordingly, Stam PCT fails to teach the following limitations in base claim 6 and by extension, claims 24-87: 1) a headlamp with *electronic circuity apparatus for the controlled powering of the light source and other illuminating device elements* and 2) a controller *in communication with the light source controlling power circuitry,* that a) per claim 6 is *arranged to processes* [*sic*] *the information communicated from the camera and automatically control the light provided to the illuminated area*; b) per representative claim 56, can be controlled to illuminate a coordinate-specific area based on *known aimings of LEDs*; c) per representative claim

24 can *emit light toward at least a portion of the other vehicle based on the LEDs having emission aimings associated with the first coordinates*; and d) per representative claim 32 *follow, based at least in part on data from one or more of the cameras, the at least one* target. *See,* Ex. OTH-F which provides each of the reexamination independent claims side-by-side, to highlight the missing limitations in all claims. (Ex. OTH-F; Ex. OTH-A at ¶80.)

Turning next to Harbers, though Harbers teaches that "spatial distribution of the light beam generated by the light source is continuously adjustable" by opto-electronic elements and thus discloses the *electronic circuitry apparatus for the controlled powering of the light source* limitation, the combination of the '538 PCT and Harbers fails to teach many of the limitations of claim 6 and the newly presented amended claims. (Ex. PA-B; Ex. OTH-A at ¶81.)

While the opto-electronic elements in Harbers are continuously adjustable by the driver or in response to a specific set of defined inputs, Harbers doesn't disclose any sensor capable of detecting objects or targets in the illuminated area, or per claim 6, a camera *for detecting coordinate-specific information about the illuminated area, said camera in communication with power and device control elements*. (Ex. PA-B; Ex. OTH-A at ¶82.)

And, although Harbers discloses "ordering, providing and selectively switching on and off opto-electronic elements…in the form of an array" in response to the velocity of the vehicle, rotational position of the steering wheel, bad weather or in dimly-lit areas (Ex. PA-B at 7:11-22), it fails to correlate individual LED controls to coordinate-specific camera/sensor data, as required by claims 6 and 24-87 and thus fails to disclose a digital headlamp that utilizes an adaptive driving beam to address glare. (Ex. OTH-C; Ex. OTH-A at ¶83.)

Thus, Harbers fails to provide any of the following limitations, in all new claim sets[3]: 1)

[3] A claim set is an independent claim and the claims that depend from that independent claim.

sensors for detecting coordinate-specific information-- *one or more sensors, including one or more cameras, placed on the structure for detecting coordinate-specific information about the illuminated area;* 2) controllers processing the sensor data- *a controller, including at least one of the one or more processors, integrated with the structure via mounting, in communication with the LED controlling power electronic circuitry apparatus, said controller arranged to process the information communicated from the cameras and to automatically control the light provided to the illuminated area;* 3) controlling an individual LED or group of LEDs within an array, responsive to coordinate-specific image detection data based on known aimings or coordinates of those LEDs, for example, per claim 48: *illuminate a portion of at least one object, indicated by data from at least one of the one or more sensors, by selecting a first cluster of the LEDs to emit first light directed towards a first area including the at least the portion of at least one object, the first area determined based at least in part on the data, the first cluster selected based at least in part on known aimings of light associated with the first cluster determined to correspond to the first area*; and 4) a control strategy that correlates LED controls to coordinate-specific sensor data of an object, to optimize illumination in a glare-free manner, for example as reflected in new claim 24: *change emission of the selected cluster of LEDs relative to emission of other LEDs not included in the cluster to create headlamp illumination that preserves a first level of illumination illuminating past the other vehicle while preventing glare to a driver of the other vehicle.* (Ex. OTH-F; Ex. OTH-A at ¶84.)

In reference to the above paragraph, Stam PCT fails to teach the last two limitations, namely controlling individual LEDs responsive to coordinate-specific image detection data, based on known aimings or coordinates of those LEDs and a control strategy that correlates individual LED controls to coordinate-specific sensor data of an object/target to diminish/enhance

illumination of a coordinate-specific region. (Ex. OTH-A at ¶85.)

Accordingly, each asserted reference individually and on combination fails to disclose one or more limitations of claim 6 and the new reexamination claims 24-87. Stam thus asserts, "it is my opinion that each reference is missing numerous features of the new claims and even if combined, the combination of Stam PCT and Harbers taken as a whole fails to teach or suggest a headlamp that correlates LED controls to coordinate specific sensor data of a target to diminish/enhance illumination at a coordinate-specific region." (Ex. OTH-A at ¶86.)

Turning to representative, new reexamination claim sets, the combination of Stam PCT and Harbers, taken as a whole fails to teach or suggest, *inter alia*, controlling an individual LED or group of LEDs within an array, responsive to coordinate-specific image detection data, so that the controller 1) per new claim 24, can *change emission of the selected cluster of LEDs relative to emission of other LEDs not included in the cluster to create headlamp illumination that preserves a first level of illumination illuminating past the other vehicle while preventing glare to a driver of the other vehicle;* 2) per new claim 32, *create a beam of diminished illumination illuminating at least a portion of the at least one target with non-glaring illumination, having different intensity than the beam, by one or more changes to characteristics of first light of a cluster of the LEDs providing the first light directed at the at least a portion and creating the beam, the beam diminished in intensity relative to the broader field of illumination illuminating at least above and on both sides of the beam; and follow, based at least in part on data from one or more of the cameras, the at least one target with the diminished illumination as the at least one target changes location relative to the motor vehicle;* and 3) per new claim 56, *select a first cluster of the LEDs based at least in part on at least one of the vertical and horizontal position compared to known aimings of light associated with the first cluster; and reduce intensity of illumination to non-*

glaring illumination of a first area associated with the at least one other vehicle, relative to intensity of illumination on both sides of the first area at elevations common with the first area illuminated by a second cluster of the LEDs, by control of emission from the first cluster. In sum, the combination of Stam PCT and Harbers provide no teachings on methods to optimize illumination—for example, high beams, which output significantly brighter light and enhance safety—in the presence of objects or upcoming curvatures in the road. (Ex. OTH-F; Ex. OTH-A at ¶¶87-88.)

Finally, as described in relation to claim 6 above, absent hindsight bias and the use of the '551 Patent as a blueprint, there is no motivation to combine the Stam PCT and Harbers references in the manner claimed. As explained in detail above, when viewed in the context of the relevant 2002-2003 time frame, a POSITA would lack motivation to combine teachings from Stam PCT and Harbers in the manner claimed, for the following reasons: 1) Stam PCT teaches away from use of individually controlled LEDs as recited in the claimed invention; 2) any hypothetical combination is inconsistent with the principle of operation of Harbers and thus a by-product of hindsight bias; and 3) during the relevant time, the evolving fields of LED technology and image detection were wholly separate fields. (Ex. OTH-A at ¶¶90-97.)

While the representative features identified above are believed to be sufficient to patentably distinguish Claim 6 and new Claims 24-87 over the prior art, these features are not exhaustive and various other patentable features included in these claims have not been described in detail for the sake of brevity.

X. Objective Indicia Supports Nonobviousness

Objective indicia, such as unexpected results, industry praise, teaching away and long-felt need, "can be the most probative evidence of non-obviousness in the record, and enable the court

to avert the trap of hindsight." *Crocs, Inc. v. ITC*, 598 F.3d 1294, 1310 (Fed. Cir. 2010). These objective criteria "turn back the clock and place the claims in the context that led to their invention." *Mintz v. Dietz,* 679 F.3d 1372, 1378 (Fed. Cir. 2012*)*. As such, the Federal Circuit requires consideration of these objective indicia because they "provide objective evidence of how the patented device is viewed in the marketplace, by those directly interested in the product." (*Demaco Corp. v. F. Von Langsdorff Licensing Ltd.,* 851 F.2d 1387, 1391 (Fed. Cir. 1988); *Spectralytics, Inc. v. Cordis Corp.,* 649 F.3d 1336, 1344 (Fed. Cir. 2011).)

As Stam concludes in his declaration, the objective evidence "in the form of long felt, but unmet need and industry praise" further "bolsters the patentability of the claimed invention--providing objective evidence that the glare-free adaptive driving beam technology claimed in the '551 Patent is nonobvious over the asserted references." (Ex. OTH-A at ¶98.)

A. Industry Praise

Over the years, numerous industry organizations, such as NHTSA, AAA and IIHS, industry publications, such as Autoweek and Driving Vision News, and Automotive Industry Awards such as the PACE Award conferred by Automotive News have provided industry praise for the glare-free adaptive beam technology (ADB) covered in claim 6 and new reexamination claims 24-87 of the '551 Patent. (Ex. OTH-A at ¶99.) A few recent examples of such industry praise, correlated to the 2018 lead up to the proposed NHTSA amendments, are provided below.[4]

[4] For purposes of this reexamination request, the NHTSA definition of ADB will be employed: "ADB systems are an advanced headlamp beam switching technology that provides increased illumination without increasing glare" utilizing advanced equipment including sensors (such as cameras), data processing software and headlamp hardware (such as shutters or LED arrays." (Ex. 4, NHTSA Proposed Rule 2018 at 2). ADB systems detect oncoming and preceding vehicles and

(Ex. OTH-A at ¶99.)

In a 2019 report AAA stated:

> Increasing roadway lighting without creating glare for other motorists should increase the safety of nighttime driving. This is the promise of adaptive driving beam headlamp technologies. NHTSA describes adaptive driving beam as, "a type of adaptive front-lighting system that automatically enables upper beam headlamps and adapts their beam patterns to create a shaded area around oncoming and preceding vehicles to improve long-range visibility for the driver without causing discomfort, distraction, or glare to other road users.

(Ex. 8, AAA 2019 report at 3, emphasis added; Ex. OTH-A at ¶100.)

The 2019 AAA report further stated:

> Auto-dimming systems (and manual high-low beam switching) are inherently limited. These systems must switch to low beam in the presence of traffic, resulting in a sharp reduction in roadway lighting. All headlamp systems which are limited to either high or low beam operation cannot avoid causing glare to other vehicles when driving on undulating roadways and cresting hills. ADB headlamp systems, with selective activation or shading of specific elements of the headlight beam, hold the promise to successfully address this major shortcoming of all current headlamp systems."

(Ex. 8 at 56, emphasis added; Ex. OTH-A at ¶101.)

An April 14, 2021 article by Autoweek explains the problem with prior automatic high-beam systems and praises the ADB technology solution:

> [e]xisting automatic high-beam headlight systems are great, but there are limitations to what they can do. If you're driving in a suburban area with traffic and

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automatically adjust the headlamp beams to provide less light to the occupied roadway and more light to the unoccupied roadway. (Ex. 4 at 2.)

> streetlights, they can become confused and leave the bright beams on when they shouldn't, or in some cases they can end up switching between low and high beam lights rapidly, which is both annoying and bad for visibility. Smart headlights help alleviate these problems by reading the road and surrounding conditions and applying light only where it is needed. Instead of the need to switch between two brightness settings, adaptive headlights' brightness and shape change in response to surrounding conditions. Where some automatic high beam systems become confused between streetlights and oncoming headlights and switch off when they shouldn't, smart headlights' advanced sensors and detection systems will eliminate the errant shifts in brightness.

(Ex. 7, Autoweek at 3, emphasis added; Ex. OTH-A at ¶102.)

The Autoweek article goes on to establish the unmet need and praise for ADB technology:

> It's no secret that the headlights on new cars are getting brighter. Now, even low beam headlights can be distracting to other drivers and pedestrians. Because adaptive headlights keep the bright lights off of pedestrians and other drivers, it's easier for people walking to stay out of the way and for other drivers to see where they're going. If there's an oncoming vehicle, the beam is partially blocked or turned off so that the other driver isn't blinded, but the rest of the road remains illuminated by bright light, which greatly improves their visibility without drastically reducing yours.

(Ex. 7 at 4, emphasis added; Ex. OTH-A at ¶103.)

Similarly, Driving Vision News states: "The benefit of a glare-free function is not only to shadow out other cars but also to provide further visibility for upcoming curves and dangerous situations; there is a clear safety gain by illuminating this curve in front of the driver." (Ex. 9, Driving Vision News at 1, emphasis added; Ex. OTH-A at ¶104.)

In his declaration and the accompanying exhibits, Stam correlates some of the above industry praise for ADB technology, side-by-side with limitations from exemplary claims and

support for these claims, to establish nexus between the industry praise and the claimed invention of the reexamination claims of the '551 Patent. *See*, Ex. OTH-E, Industry praise nexus support document. In the right-hand column of that document, Stam correlates the industry praise verbiage with the claim limitations and provides an exemplary explanation, as to how a person of skill in the art would understand the praise verbiage. (Ex. OTH-A at ¶¶105-106.)

By way of example, the Stam declaration correlates each limitation of claim 24 with the industry praise verbiage and an explanation of the nexus between the two. Notably, the rationale articulated with respect to claim 24 applies to all similar limitations in claim 6 and the other new claims. *See,* OTH-E; Ex. OTH-A at ¶107.

On the issue of nexus, Stam opines first in reference to the preamble in claim 24, *[a]n illuminating device having automatic control of the light provided to an illuminated area comprising*, and the praise verbiage from the PACE Award Automotive News article provides: HELLA "has won the prestigious 2014 Automotive News PACE Award for its industry-first adaptive LED Matrix Beam technology. . . HELLA's "glare-free high-beam" **headlights use individually controlled LEDs that adjust automatically** to real-time traffic conditions to reduce glare for other drivers" (Ex. 10 PR Newswire at 1.) With respect to the preamble and the cited praise verbiage, Stam states "[i]t is my opinion that, from the described functionality, it's clear to a person skilled in the art that the praise is directed to an *illuminating device* as laid out in the preamble." (Ex. OTH-A at ¶108; OTH-E at 1, 10, 27 and 45.)

The declaration next addresses the limitation in claim 24, *a structure for incorporating illuminating device elements* and the praise verbiage from the PACE Award Automotive News article which provides: "The system automatically adjusts **a car's headlamps** to deliver 'glare free' illumination, dimming or switching on and off light sources based on traffic conditions."

(Ex. 10, PR Newswire at 1; Ex. OTH-E, '551 Industry praise nexus support document.) In reference to the above claim limitation and praise verbiage, Stam states: "[i]t is my opinion that, from the described functionality, it's clear to a person skilled in the art that the praise is directed to *a structure for incorporating illuminating device elements."* (Ex. OTH-A at ¶109; Ex. OTH-E at 1, 11, 27 and 45.)

The declaration addresses the limitation in claim 24, *a plurality of individually controllable LEDs incorporated in the structure via at least one headlamp mounted to the structure, each headlamp including at least one of the LEDs, the LEDs in communication with a power source* and the praise verbiage from the PACE Award Automotive News article provides: HELLA "has won the prestigious 2014 Automotive News PACE Award for its industry-first adaptive LED Matrix Beam technology. . . HELLA's "glare-free high-beam" **headlights use individually controlled LEDs that adjust automatically** to real-time traffic conditions to reduce glare for other drivers" (Ex. 10 at 1.) In reference to the above claim limitation and praise verbiage, Stam states:

> [i]t is my opinion that, from the described functionality, it's clear to a person skilled in the art that the praise is directed to the limitation *a plurality of individually controllable LEDs incorporated in the structure via at least one headlamp mounted to the structure, each headlamp including at least one of the LEDs, the LEDs in communication with a power source.*

(Ex. OTH-A at ¶110; Ex. OTH-E at 5, 14, 30-31, 48.)

The declaration addresses the limitation in claim 24, *electronic circuitry apparatus for the controlled powering of the LEDs and other of the illuminating device elements* and the praise verbiage from the PACE Award Automotive News article which provides:

> HELLA . . . has won the prestigious 2014 Automotive News PACE Award for its

> industry-first adaptive LED Matrix Beam technology. . . HELLA's "glare-free high-beam" **headlights use individually controlled LEDs that adjust automatically** to real-time traffic conditions to reduce glare for other drivers. The system automatically adjusts **a car's headlamps** to deliver 'glare free' illumination, dimming or switching on and off light sources based on traffic conditions.

(Ex. 10 at 1, emphasis added.)

In reference to the above claim limitation and praise verbiage, Stam states: "[i]t is my opinion that, from the described functionality, it's clear that the praise is directed to an illuminating device, including *electronic circuitry apparatus for the controlled powering of the LEDs and other of the illuminating device elements*." (Ex. OTH-A at ¶111; Ex. OTH-E at 7, 16, 33 and 51.)

The declaration addresses the limitation in claim 24, *one or more sensors, including one or more cameras, placed on the structure for detecting coordinate-specific information about the illuminated area, at least one of said cameras in communication with power, and in communication with at least one of the one or more processors* and the praise verbiage from the PACE Award Automotive News article: "The **new Matrix Beam system combines a front camera**, high-performance software and "intelligent lighting" technology **to recognize cars that are being followed as well as oncoming traffic**." (Ex. 10 at 1, emphasis added.) In reference to the above claim limitation and praise verbiage, Stam states: "[i]t is my opinion that, from this sentence, it's clear to a person skilled in the art that the industry praise is directed to an illuminating device that includes the details of the camera sensor limitation." (Ex. OTH-A at ¶112; Ex. OTH-E at 8, 17, 34, and 52.)

The declaration addresses the limitation in claim 24, *a controller, including at least one of the one or more processors, integrated with the structure via mounting, in communication with the LED controlling power electronic circuitry apparatus, said controller arranged to process the*

information communicated from the cameras and to automatically control the light provided to the illuminated area and the praise verbiage from the PACE Award Automotive News article which provides:

> A leader in automotive lighting and electronics, HELLA's "glare-free high-beam" headlights **use individually controlled LEDs that adjust automatically to real-time traffic conditions** to reduce glare for other drivers. **The new Matrix Beam system combines a front camera, high-performance software and "intelligent lighting" technology to recognize cars that are being followed as well as oncoming traffic**.
>
> **The system automatically adjusts a car's headlamps to deliver "glare free" illumination, dimming or switching on and off light sources based on traffic conditions**.

(Ex. 10 at 1, emphasis added.)

In reference to the above claim limitation and praise verbiage, Stam states: "[i]t is my opinion that, from the above sentences and the inherent knowledge possessed by a person skilled in the art, it's clear that the industry praise is directed to an illuminating device that includes the details of the controller limitation, wherein the controller processes information from the camera." (Ex. OTH-A at ¶113; Ex. OTH-E at 9-10, 18-19, 35-36, 53-54.)

The declaration addresses the limitation in claim 24, *memory storing instructions that, when executed by one or more processors of the controller, enable the controller to,* and the praise verbiage from the PACE Award Automotive News article which provides:

> A leader in automotive lighting and electronics, HELLA's "glare-free high-beam" headlights **use individually controlled LEDs that adjust automatically to real-time traffic conditions** to reduce glare for other drivers. **The new Matrix Beam system combines a front camera, high-performance software and "intelligent**

lighting" technology to recognize cars that are being followed as well as oncoming traffic.

The system automatically adjusts a car's headlamps to deliver "glare free" illumination, dimming or switching on and off light sources based on traffic conditions.

(Ex. 10 at 1, emphasis added.)

In reference to the above claim limitation and praise verbiage, Stam states: "[i]t is my opinion that, from the above sentences and the inherent knowledge of a person skilled in the art, in order to implement the "high performance software" it's clear that *memory storing instructions*" would necessarily be provided." (Ex. OTH-A at ¶114; Ex. OTH-E at 20, 36-37, and 54-55.)

The declaration addresses the limitation in claim 24, *enable the controller to . . determine first coordinates corresponding to an other vehicle, based on the coordinate-specific information*, and the praise verbiage from the PACE Award Automotive News article which provides:

A leader in automotive lighting and electronics, HELLA's "glare-free high-beam" headlights **use individually controlled LEDs that adjust automatically to real-time traffic conditions** to reduce glare for other drivers. **The new Matrix Beam system combines a front camera, high-performance software and "intelligent lighting" technology to recognize cars that are being followed as well as oncoming traffic**.

The system automatically adjusts a car's headlamps to deliver "glare free" illumination, dimming or switching on and off light sources based on traffic conditions.

(Ex. 10 at 1, emphasis added.)

In reference to the above claim limitation and praise verbiage, Stam states: "[i]t is my

opinion that, from the above sentences and the inherent knowledge of a person skilled in the art, it's clear that the industry praise is directed to an illuminating device that determines the position of at least one other vehicle." (Ex. OTH-A at ¶115; Ex. OTH-E at 20-21, 42, and 55-56.)

The declaration addresses the limitation in claim 24, enable the controller to . . . *select a cluster of the LEDs that emit light toward at least a portion of the other vehicle based on the LEDs having emission aimings associated with the first coordinates*, and the praise verbiage from the PACE Award Automotive News article:

> The new Matrix Beam system combines a front camera, high-performance software and "intelligent lighting" technology to recognize cars that are being followed as well as oncoming traffic.
>
> The system automatically adjusts a car's headlamps to deliver "glare free" illumination, dimming or switching on and off light sources based on traffic conditions.
>
> **Individually controlled LEDs also provide two or more dark zones with "light in-between," allowing continuous use of a vehicle's high-beams to maximize visibility and provide a safer driving experience**.

(Ex. 10 at 1, emphasis added.)

In reference to the above claim limitation and praise verbiage, Stam states: "[i]t is my opinion that, from the above sentences and the inherent knowledge of a person skilled in the art, an illuminating device that includes "individually controlled LEDs" necessarily selects the LEDS to be aimed based on the position of the detected vehicle, per the *select a cluster* limitation." (Ex. OTH-A at ¶116; Ex. OTH-E at 22-23 and 56-57.)

The declaration addresses the limitation in claim 24, enable the controller to . . . *change emission of the selected cluster of LEDs relative to emission of other LEDs not included in the*

cluster to create headlamp illumination that preserves a first level of illumination illuminating past the other vehicle while preventing glare to a driver of the other vehicle and the praise verbiage from the PACE Award Automotive News article:

> The new Matrix Beam system combines a front camera, high-performance software and "intelligent lighting" technology to recognize cars that are being followed as well as oncoming traffic.
>
> The system automatically adjusts a car's headlamps to deliver "glare free" illumination, dimming or switching on and off light sources based on traffic conditions.
>
> **Individually controlled LEDs also provide two or more dark zones with "light in-between," allowing continuous use of a vehicle's high-beams to maximize visibility and provide a safer driving experience**.

(Ex. 10 at 1, emphasis added.)

In reference to the above claim limitation and praise verbiage, Stam states: "[i]t is my opinion that, from the above sentences it would be clear to a person skilled in the art that the industry praise description of an illuminating device with "two or more dark zones with 'light-in-between" to maximize visibility, corresponds to the above-identified claim limitation, providing reduced illumination in the dark zones relative to the illumination on both sides of the dark zone." (Ex. OTH-A at ¶117; Ex. OTH-E at 24-25, 42, and 61-62.)

As evidenced by the nexus established above in regards to claim 24 and as further shown in OTH-E, which establishes nexus between representative claims 6, 24, 32 and 56 and exemplary industry praise verbiage, this objective indicia of industry praise bolsters the nonobviousness of claim 6 and the new reexamination claims 24-87. In his declaration, Stam underscores the role of the nexus evidence: "the objective evidence of industry praise with a nexus to the reexamination

claims supports my underlying conclusion that the Glare-Free Adaptive Driving Beam system covered in the reexamination claims are nonobvious over the combination of Stam PCT and Harbers and are thus patentable." (Ex. OTH-A at ¶118; Ex. OTH-E at 10.)

B. Long Felt but Unmet Need

Automotive companies and the industry at large have long recognized the two-fold need for 1) increased visibility at night and 2) avoiding the discomfort of glaring headlamps. (Ex. OTH-A at ¶119.)

This two-fold need was first solved by the glare-free adaptive driving beam systems described by Spero in the '551 Patent, which gave rise to claim 6 and the new reexamination claims, supported by the 2002 provisional application filing by Spero. (Ex. OTH-A at ¶120.)

As evidenced by contemporaneous prior art filings in 2002-2003, LED technology was in nascent stages and not viewed as suitable for headlamp applications. In 2003 and for several years thereafter, those skilled in the art of auto headlight design and controls used LEDs for taillights and interior spotlights but not front headlights. By way of example, see EP1391347, filed by Hella in 2002 which is directed to a pivoting, auto high-beam lamp devoid of any teaching of the use of LEDs and U.S. Patent No. 6,752,523 filed in 2002 by Koito, which discloses the use of LEDs for taillights but not headlights. It was not until 2006–2009 that automotive lighting companies began filing patents directed to digital headlights for adaptive driving beam technology (Ex. OTH-G, Krukenbaum '347 patent; Ex. OTH-H, Takahashi '523 patent; Ex. OTH-A at ¶121.)

Notably, LED headlights were first used in vehicles in 2007-2008. *See*, Toyota's use of a partial LED headlight in 2007 and Audi's introduction of full LED headlights in 2008 (Ex. 1; Ex. 2; Ex. OTH-A at ¶121.)

Despite the launch of LED headlights in 2007-2008, regulatory restrictions by the National

Highway Traffic Safety Administration (NHTSA) have prevented adaptive driving beam technology from activation in the US, though such technology has been employed outside the US for years. For a period of several years, starting in 2013, OEMs petitioned NHTSA for a change in regulations. In 2018, NHTSA announced proposed rules to amend the regulations to allow adaptive driving beam technology. (Ex. 4, NHTSA Proposed Rule 2018 at 1; Ex. OTH-A at ¶122.) In July 2020, Alliance for Automotive Innovation ("Auto Innovators") consisting of OEMs provided supplemental comments to the NHTSA notice of proposed rulemaking detailing their position on the proposed rulemaking. (Ex. 11, Alliance for Automotive Innovation at 1.)

The supplemental comment filed by the Alliance for Automotive Innovation, makes a compelling case for why the prior art auto-high beam applications did not satisfy the long-felt need for "adaptive driving beam technology," which refers to adaptive LED headlights that address high beam glare through coordinate-specific control strategies (Ex. 11). By way of example, the Alliance for Automotive Innovation, which includes the majority of the global auto industry, acknowledged that "an average of 0.3% of nighttime fatal crashes list glare as a contributing factor, alternatively data shows that over 70% of pedestrian fatalities have occurred at night." (Ex. 11 at 8, emphasis added; Ex. OTH-A at ¶123.)

One industry publication from 2014, underscores the long felt, but unmet need for a glare-free headlight that optimizes illumination: "[e]ven after 130 years of headlight development, more than half of vehicle crashes and fatalities occur at night despite significantly less traffic. More than 300,000 crashes and thousands of fatalities are caused by rain and snow at night annually. Approximately 30% of drivers are stressed by glare causing hundreds of fatalities every year." (Ex. 3, Tamburo R. (2014) at 1-2, emphasis added; Ex. OTH-A at ¶124.)

According to AAA, vehicle headlamps are a primary safety system:

> Research data from the National Highway Traffic Safety Administration (NHTSA) reports approximately 25 percent of automotive travel occurs at night. However, nearly 52 percent of all driver fatalities and 71 percent of all pedestrian deaths occur during dark driving times . This data leads to the conclusion that driving in dark or low-light conditions increases the likelihood of a collision at least partially due to a combination of limited forward illumination by current automotive lighting systems and the speeds at which drivers travel . The efficacy of headlamps compliant with U.S. regulations may be a contributing factor. Research conducted by AAA determined that modern headlamps on low beam provide adequate lighting for speeds of only 39 mph to 52 mph, depending on the type of headlamp

(Ex. 8, AAA 2019 report at 3, emphasis added; Ex. OTH-A at ¶120.)

Notably, as part of NHTSA's proposed rulemaking in 2018, NHTSA provided an extensive summary of why a long-felt unmet need exists for adaptive driving beam technology. Excerpts of the NHTSA summary are reproduced below to establish that during the relevant 2002-2003 time period, a long-felt need existed for the glare-free adaptive beam technology [ADB] covered in the reexamination claims of the '551 Patent. (Ex. OTH-A at ¶126.)

Based on the definitions of ADB in the NHTSA Proposed rulemaking, specifically the sections boldfaced below, claim 6 and new claims 24- 87 of the '551 Patent are directed to an Adaptive Driving Beam [ADB] system (Ex. OTH-A at ¶127). The underlined quotes in the below excerpt, provide strong evidence that the ADB system covered by in the '551 reexamination claims satisfies a long-felt but unmet need:

> While the benefits of improved visibility and the harmful effects of glare are difficult to quantify, they are real. For example, a recent study from the Insurance Institute for Highway Safety found that pedestrian deaths in dark conditions increased 56% from 2009 to 2016. The harmful effects of glare are highlighted by

the thousands of consumer complaints NHTSA has received from the public over the years, Congressional interest, and the Agency's research. NHTSA received more than 5,000 comments in response to a 2001 Request for Comments on glare from headlamps and other frontal vehicle lamps**.** Most of these comments concerned nighttime glare. In 2005, Congress directed the Department of Transportation to study the risks of glare. In response to these concerns, NHTSA initiated a multipronged research program to study the risks of, and possible solutions to, glare. **ADB [Adaptive Driving Beam] systems are an advanced type of headlamp beam switching technology that provides increased illumination without increasing glare**. Headlamp beam switching were first introduced in the 1950s, and while not initially widely adopted, have more recently become widely offered as optional equipment. These traditional beam switching systems switch automatically from the upper beam to the lower beam when meeting other vehicles. **ADB systems improve on this technology. They utilize advanced equipment, including sensors (such as cameras), data processing software, and headlamp hardware (such as shutters or LED arrays). ADB systems detect oncoming and preceding vehicles and automatically adjust the headlamp beams to provide less light to the occupied roadway and more light to the unoccupied roadway. ADB technology enhances safety in two ways. First, it provides a variable, enhanced lower beam pattern that is sculpted to traffic on the road, rather than just one static lower beam pattern. It provides more illumination than existing lower beams without glaring other motorists (if operating correctly Second, it likely will lead to increased upper beam usage**. Research has shown that most drivers under-utilize the upper beams. The effects of this increase as speeds increase, because at higher speeds the need for greater seeing distance increases. ADB technology (like traditional beam switching technology) enables the driver to activate the ADB system so that it is always in use and there is no need to switch between lower beams and upper beams. In this way, the upper beam will be more widely used, and used only when there are no other vehicles present. For both these reasons, ADB has the potential to reduce the risk of crashes by increasing visibility without increasing glare. In particular, it offers potentially significant

safety benefits in avoiding collisions with pedestrians, cyclists, animals, and roadside objects.

"Background & Safety Need

ADB technology is an advanced type of semiautomatic headlamp beam switching technology. More rudimentary beam switching technology was first introduced in the 1950s and was limited simply to switching between upper and lower beams. **Adaptive driving beam technology is more advanced. It uses advanced sensors and computing technology that more accurately and precisely detect the presence and location of other vehicles and shape the headlamp beams to provide enhanced illumination of unoccupied portions of the road and avoid glaring other vehicles."**

"The Twin Safety Needs of Glare

Vehicle headlamps must satisfy two different safety needs: Visibility and glare prevention. Headlamps provide forward visibility (and also work in conjunction with parking lamps on passenger cars and other narrow vehicles to provide conspicuity). They also have the potential to glare other motorists and road users. For this reason, headlighting systems include a lower beam and an upper beam. Lower beams (also referred to as passing beams or dipped beams) illuminate the road and its environs close ahead of the vehicle and are intended for use during low speed driving or when meeting or closely following another vehicle. Upper beams (also referred to as high beams, main beams, or driving beams) are intended primarily for distance illumination and for use when not meeting or closely following another vehicle. The lower beam pattern is designed to produce relatively high levels of light only in the close-in forward visibility region; the upper beam is designed to produce high light levels in close-in and longer distance regions**. Thus, headlighting has traditionally entailed a trade-off between forward longer-distance visibility for the driver and glare to other road users.**

Visibility and glare are both related to motor vehicle safety. Visibility has an

obvious, intuitive relation to safety: The better a driver can see the road, the better he or she can react to road conditions and obstacles and avoid crashes. Although the qualitative connection to safety is intuitive, quantifying the effect of visibility on crash risk is difficult because of many confounding factors (for example, was the late-night crash because of diminished visibility or driver fatigue?). Glare, again intuitively, is related to safety because it degrades a driver's ability to see the forward roadway and any unexpected obstacles. Glare is a sensation caused by bright light in an observer's field of view. It reduces the ability to see and/or causes discomfort. Headlamp glare is the reduction in visibility and discomfort caused by viewing headlamps of oncoming or trailing vehicles (via the rearview or side mirrors).1 Empirical evidence suggests that headlamp glare degrades important aspects of driving performance, such as decreasing the distance at which an object in or near the roadway can be seen, increasing driver reaction times, and reducing the probability a driver will detect an object.2 It is difficult, however, to quantify the effect of glare on crash risk.

The potential problems associated with glare are highlighted by the thousands of complaints NHTSA has received from the public on the issue. The introduction of halogen headlamp technology in the late 1970s and high intensity discharge and auxiliary headlamps in the 1990s was accompanied by a marked upswing in the number of glare complaints to NHTSA. In response to increased consumer complaints about glare in the late 1990s, NHTSA published a Request for Comments in 2001 on issues related to glare from headlamps, fog lamps, driving lamps, and auxiliary headlamps. NHTSA received more than 5,000 comments, most of which concerned nighttime glare from front mounted lamps."

(Ex. 4 at 2-5, emphasis added; Ex. OTH-A at ¶127.)

Based on the above examples of industry praise, teaching away, and long felt but unmet need and their nexus to the claimed invention, there is "sufficient objective evidence that the '551

Patent was not obvious during the relevant time frame and given the state of the industry at that time." (Ex. OTH-A at ¶127.)

XI. Conclusion

The prior art documents presented in the above Request were not previously considered by the Office pursuant to MPEP § 2242.

Claim 6 and new claims 24 – 87 of the '551 Patent are patentable over the prior art documents cited herein. The prior art documents teach the subject matter of the '551 Patent in a manner such that a substantial new question of patentability for Claim 6 is raised by this Request. Accordingly, the Office is requested to grant this Request and to initiate reexamination with special dispatch.

Respectfully submitted,

Dated: July 30, 2021

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PTO/SB/57 (01-18)
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(Also referred to as FORM PTO-1465)

REQUEST FOR *EX PARTE* REEXAMINATION TRANSMITTAL FORM

Address to:
Mail Stop *Ex Parte* Reexam
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Attorney Docket No.: TRCH0102RX

Date: July 30, 2021

1. ☒ This is a request for *ex parte* reexamination pursuant to 37 CFR 1.510 of patent number 9,955,551 issued April 24, 2018. The request is made by:
   ☒ patent owner. ☐ third party requester.

2. ☒ The name and address of the person requesting reexamination is:
   Yechezkal Evan Spero
   20 Rashi St.
   Moshav Tifrach, Israel 85102

3. Requester ☐ asserts small entity status (37 CFR 1.27) or ☐ certifies micro entity status (37 CFR 1.29). Only a patent owner requester can certify micro entity status. Form PTO/SB/15A or B must be attached to certify micro entity status.

4. This request is accompanied by payment of the reexamination fee as set forth in:
   ☒ 37 CFR 1.20(c)(2); **or**
   ☐ 37 CFR 1.20(c)(1). **In checking this box for payment of the fee set forth in 37 CFR 1.20(c)(1), requester asserts that this request has forty (40) or fewer pages and complies with all other requirements of 37 CFR 1.20(c)(1).**

   Payment of the reexamination fee is made by the method set forth below.
   a. ☐ A check in the amount of $_____ is enclosed to cover the reexamination fee;
   b. ☐ The Director is hereby authorized to charge the reexamination fee to Deposit Account No. _____;
   c. ☐ Payment by credit card. Form PTO-2038 is attached; **or**
   d. ☒ Payment made via EFS-Web.

   ☒ In addition, the Director is hereby authorized to charge any fee deficiencies to Deposit Account No. 023978.

5. ☒ Any refund should be made by ☐ check or ☒ credit to Deposit Account No. 023978. 37 CFR 1.26(c). If payment is made by credit card, refund must be to credit card account.

6. ☒ A copy of the patent to be reexamined having a double column format on one side of a separate paper is enclosed. 37 CFR 1.510(b)(4).

7. ☐ CD-ROM or CD-R in duplicate, Computer Program (Appendix) or large table
   ☐ Landscape Table on CD

This collection of information is required by 37 CFR 1.510. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) a request for reexamination. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 18 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Mail Stop *Ex Parte* Reexam, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

8. ☐ Nucleotide and/or Amino Acid Sequence Submission
If applicable, items a. -- c. are required.
   a. ☐ Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. ☐ CD-ROM (2 copies) or CD-R (2 copies) **or**
      ii. ☐ paper
   c. ☐ Statements verifying identity of above copies.

9. ☐ A copy of any disclaimer, certificate of correction or reexamination certificate issued in the patent is included.

10. ☒ Reexamination of claim(s) 6 is requested.

11. ☒ A copy of every patent or printed publication relied upon is submitted herewith including a listing thereof on Form PTO/SB/08, PTO-1449, or equivalent.

12. ☐ An English language translation of all necessary and pertinent non-English language patents and/or printed publications is attached.

13. ☒ The attached detailed request includes at least the following items:
   a. A statement identifying each substantial new question of patentability based on prior patents and printed publications. 37 CFR 1.510(b)(1).
   b. An identification of every claim for which reexamination is requested, and a detailed explanation of the pertinency and manner of applying the cited art to every claim for which reexamination is requested. 37 CFR1.510(b)(2).

14. ☒ A proposed amendment is included (only where the patent owner is the requester). 37 CFR 1.510(e).

15. ☒ It is certified that the statutory estoppel provisions of 35 U.S.C. 315(e)(1) or 35 U.S.C. 325(e)(1) do not prohibit requester from filing this *ex parte* reexamination request. 37 CFR 1.510(b)(6).

16. Service
   a. ☐ It is certified that a copy of this request (if filed by other than the patent owner) has been served in its entirety on the patent owner as provided in 37 CFR 1.33(c).

      The name and address of the party served are:

      _____

      _____

      _____

      Date of Service: _____

   OR

   b. ☐ A duplicate copy is enclosed since service on patent owner was not possible. An explanation of the efforts made to serve patent owner **is attached**. See MPEP 2220.

17. Correspondence Address: Direct all communication about the reexamination to:

☒ The address associated with Customer Number: 22045

OR

☐ Firm or Individual Name _____
(at the address identified below)

Address

City	State	Zip

Country

Telephone	Email

18. ☒ The patent is currently the subject of the following concurrent proceeding(s):

a. ☒ Copending reissue Application No. 16858342

b. ☐ Copending reexamination Control No. _____

c. ☐ Copending Interference No. _____

d. ☐ Copending litigation styled:

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_____

WARNING : Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

/Sangeeta G. Shah/ — Authorized Signature

July 30, 2021 — Date

Sangeeta G. Shah — Typed/Printed Name

38,614 — Registration No.

☒ For Patent Owner Requester ☐ For Third Party Requester

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PTO/AIA/81B (07-13)
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REEXAMINATION OR SUPPLEMENTAL EXAMINATION – PATENT OWNER POWER OF ATTORNEY OR REVOCATION OF POWER OF ATTORNEY WITH A NEW POWER OF ATTORNEY AND CHANGE OF CORRESPONDENCE ADDRESS FOR REEXAMINATION OR SUPPLEMENTAL EXAMINATION AND PATENT

Control Number(s)	Not Yet Assigned
Filing Date(s)	
First Named Inventor	Yechezkal Evan Spero
Title	Detector Controlled Illuminating System
Patent Number	9,955,551 B2
Examiner Name	N/A
Attorney Docket No(s)	TRCH0102RX

I. **Power of Attorney**. This form may be used to change the Power of Attorney in a reexamination or supplemental examination proceeding (or multiple proceedings where merged). This form may also be used to change the Power of Attorney in the patent file; in such a case, a copy of this form will be placed in both the patent file and the reexamination or supplemental examination proceeding.

A. Revocation of Previous Power of Attorney. I hereby revoke all previous patent owner powers of attorney, if any, given:

☒ in the above-identified reexamination or supplemental examination proceeding control number(s) (more than one may be changed only if the proceedings are merged).

☒ in the file of the above-identified patent.

(check BOTH boxes if change in BOTH the patent file and the reexamination or supplemental examination proceeding is requested).

B. Designation of Power of Attorney.

☐ A Power of Attorney is submitted herewith.

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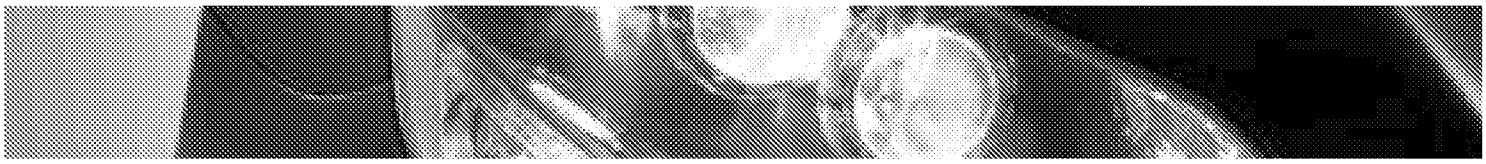
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Exhibit 1
Motor Authority



A look at the new LED headlights on the Lexus LS600h

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After the enormous interest in our previous story on the new LED headlights in the Audi R8, we've decided to give you the latest updates to the LED system Lexus plans to introduce in the flagship LS 600h. Unlike the all-LED system that Audi will debut on its R8 sports car at the end of the year, the Lexus units only use the efficient diodes for its low-beam projectors.

Lexus will still offer conventional halogen lamps or optional xenon units but the advantage of LEDs is as clear as night and day. The average life span of LEDs is approximately 15 years without any reduction in the light beam's intensity or color. They are also very reliable, maintenance free, and the light response time is very quick, taking just 0.1 of second to reach full intensity.

Their best feature, however, is the ultra-low power usage, which in turn leads to less fuel consumption and carbon-dioxide emissions. The two headlight units of the Lexus LS 600h consist of three LED lenses for the headlight low beam, two LEDS for illuminating close range and a xenon headlight for the high beam.

The headlights can also swivel up to 20 degrees from center depending on the steering angle and the given speed of the vehicle, and automatically reduces brightness when approaching oncoming traffic.

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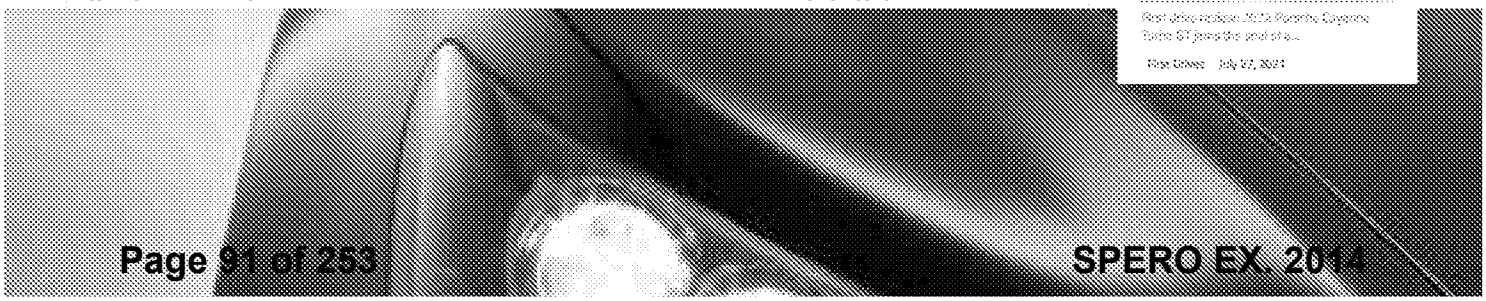
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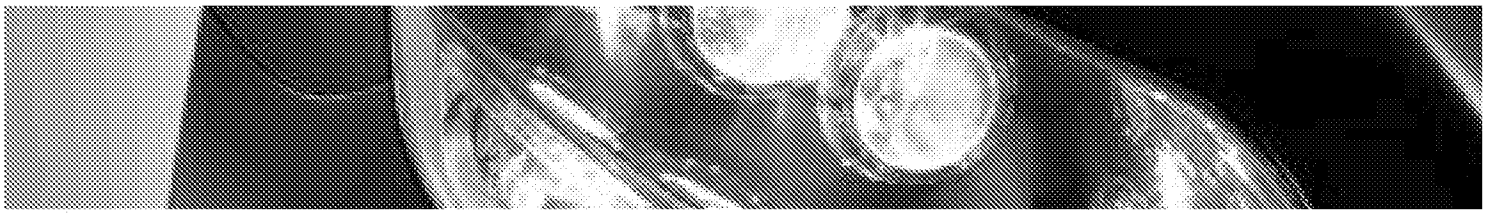
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Exhibit 2
Audi Technology Portal

LED headlights

The LED headlights are an area of technology in which Audi is well ahead of the competition. They were introduced in 2008 on the R8 high-performance sports car; since then the brand with the four rings has repeatedly extended its lead.

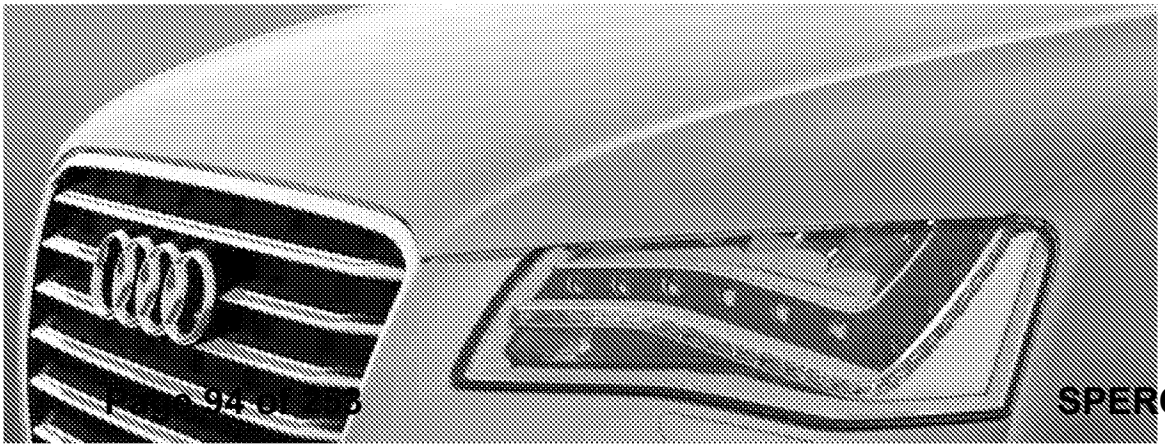
The LED headlights give the Audi vehicles for which they are available an unmistakably striking appearance, even in daylight, and even more so after the fall of darkness. With a color temperature of around 5,500 Kelvin, their light resembles daylight and thus is much less tiring for the eyes. The light-emitting diodes are zero-maintenance and designed for the life of the vehicle. They also shine in terms of efficiency with their low power consumption. The low beams, for example, consume only around 40 watts per unit, which is less than the already highly efficient xenon plus headlights and much less than conventional halogen headlights.

The innovative technology of the full LED headlights led to a radically new and fascinating design. On the Audi A8, for instance, the low beams comprise ten individual lens modules extending through the headlight in a distinctive arc below the chrome contour known as the wing, on account of its shape. Just below this is another arc of 22 white and 22 yellow LEDs for the daytime running lights and the turn signals. Their thick wall technology makes them appear to the onlooker as homogenous, continuous strips of light.

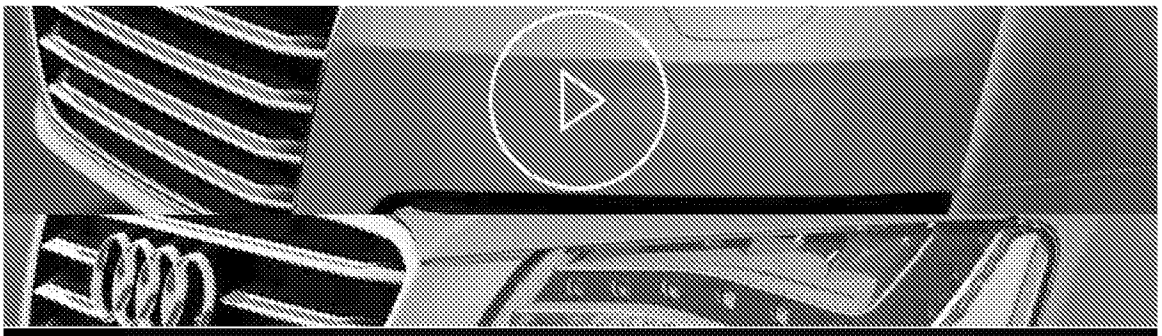
The high-beam headlights are located above the wing. Their light is generated by two powerful four-chip LEDs and a free-form reflection system; an assistance function switches between the low and high beams. Additional high-output LEDs generate the highway light and the cornering light. A separate fan and heat sink moderate the temperature of each headlight unit.

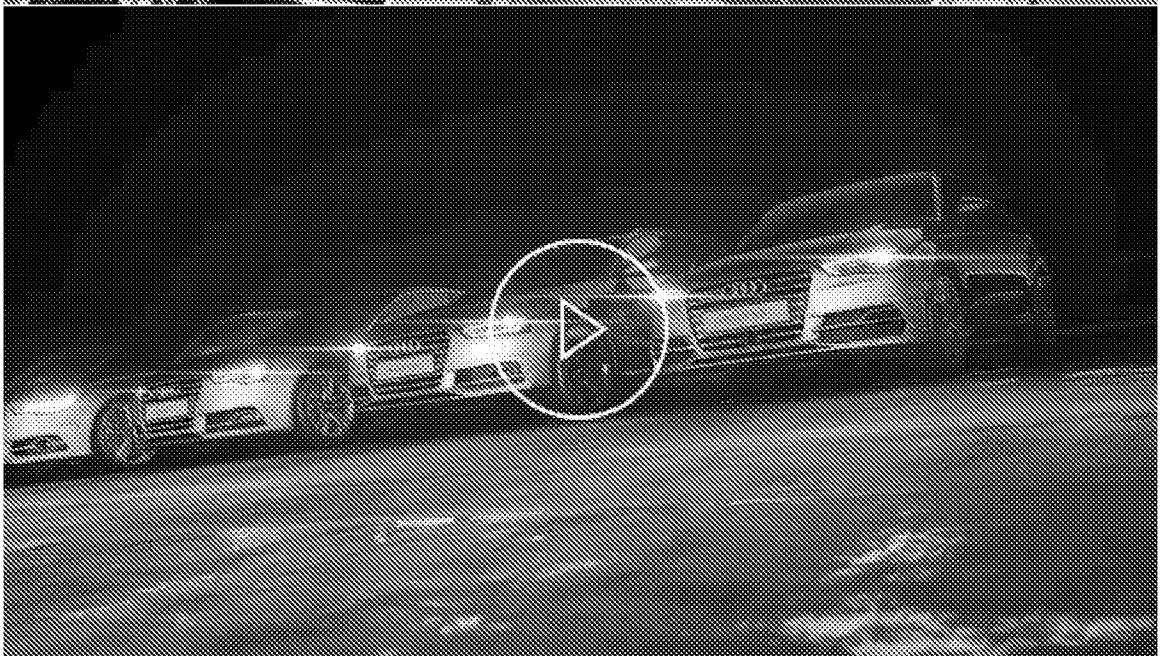
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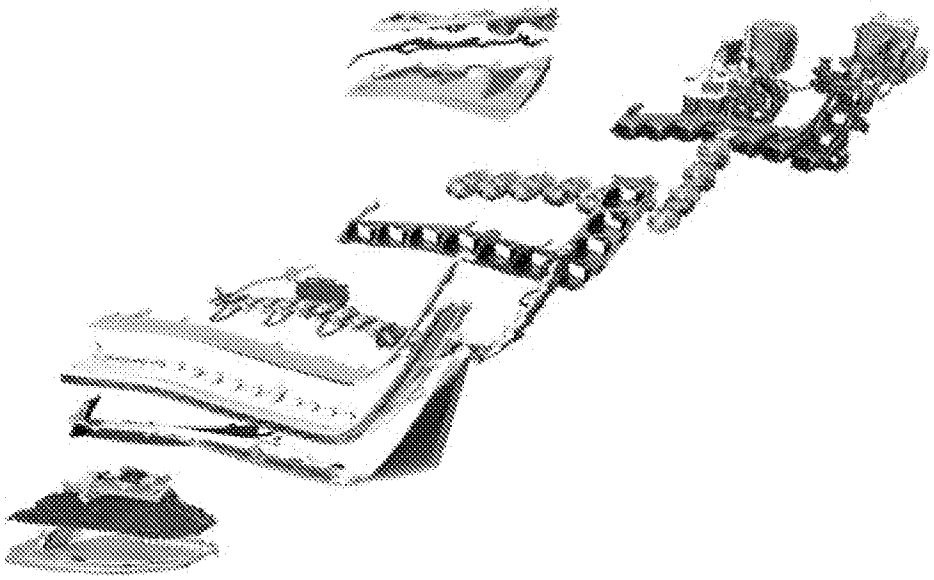




Audi LED lighting technology



Systematically efficient: the LED headlights in the Audi A8



Highly integrated system: Audi is the leader in LED technology

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Exhibit 3
Programmable Automotive Headlights
Tamburo et al. 2014

Programmable Automotive Headlights

Robert Tamburo[1], Eriko Nurvitadhi[2], Abhishek Chugh[1], Mei Chen[2], Anthony Rowe[1], Takeo Kanade[1], Srinivasa G. Narasimhan[1]

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Abstract. The primary goal of an automotive headlight is to improve safety in low light and poor weather conditions. But, despite decades of innovation on light sources, more than half of accidents occur at night even with less traffic on the road. Recent developments in adaptive lighting have addressed some limitations of standard headlights, however, they have limited flexibility - switching between high and low beams, turning off beams toward the opposing lane, or rotating the beam as the vehicle turns - and are not designed for all driving environments. This paper introduces an ultra-low latency reactive visual system that can sense, react, and adapt quickly to any environment while moving at highway speeds. Our single hardware design can be programmed to perform a variety of tasks. Anti-glare high beams, improved driver visibility during snowstorms, increased contrast of lanes, markings, and sidewalks, and early visual warning of obstacles are demonstrated.

Keywords: Adaptive headlights, reactive visual system, computational illumination

1 Introduction

Traditional headlights consist of a small number of lamps with simple optics to direct a light beam onto the road. Starting with gas/oil lamps in the 1880s, research has been primarily geared towards developing headlights that can be electrically controlled, have a long working life, and are bright and energy efficient. The inventions of Halogen lamps, Xenon (HID) lamps [4], [5], and the more recent LED [1], [2] and Laser sources [9] have followed this research trend. These latest sources provide bright and comfortable color temperatures improving driving experiences. However, even with these new light sources the only control offered to a majority of drivers is to switch between high and low beams.

Low beams illuminate the road a short range in front of the vehicle while high beams have a longer range and wider angle. High beams are useful in a variety of situations providing better visibility farther down the road and along narrow, curvy roads. However, they cause significant glare to other drivers, bicyclists, and pedestrians. High beams also significantly reduce contrast in the presence of fog and haze, and cause bright distracting streaks during precipitation events. Even after 130 years of headlight development, more than half of vehicle crashes and

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fatalities occur at night despite significantly less traffic [14]. More than 300,000 crashes and thousands of fatalities are caused by rain and snow at night annually [14]. Approximately 30% of drivers are stressed by glare causing hundreds of fatalities every year [12]. Thus, a headlight that adapts to the environment can be critical to improving safety on the road during poor visibility conditions.

Recognizing the limitations of traditional headlights, adaptive lighting systems have been developed to adjust their brightness in response to changing driving conditions. Some systems, e.g. Lincoln [6], Audi [2], Volkswagen [7], mechanically swivel the headlight based on the vehicle's turning radius allowing drivers to see around curved roads. Other systems use configurations of multiple LEDs, where individual LEDs can be automatically turned off toward the driving lane and/or the opposing lane to reduce glare, e.g., BMW [21], Audi [22], Mercedes [23], and Volvo [24]. In [9] swiveling LEDs spotlight pedestrians on sidewalks. These advanced systems have come a long way from traditional headlights, but fundamental issues remain: they are not versatile and are designed for one-off applications, they require mechanical components that reduce reliability, and their low-resolution and high latency limits them from adapting to many types of road conditions and poor visibility situations.

This paper presents a new computational illumination design for an automotive headlight that is flexible and can be programmed to perform multiple tasks at high speeds. The key idea is the introduction of a high-resolution spatial light modulator (SLM) such as the digital micro-mirror device (DMD) present in DLP projectors. A DMD divides a light beam into approximately one million beams that can be individually controlled to shape the collective beam for any situation. A sensor (camera) is co-located with the light source and a computer processes images to generate illumination patterns for the SLM. While the design may seem straightforward and follows many works on projector-camera systems in computer vision, there are many challenges in building such a system to serve as a headlight. The accuracy requirements can be high since small errors in beam positioning and flickering are easily perceived and can be more disturbing than standard headlights. High accuracy can be achieved by minimizing the time from when a camera senses the environment to when the headlight reacts (system latency). Low latency is also required to avoid the need for complex prediction algorithms to determine where an object will move next.

A prototype system was built with an ultra-low latency of 1 to 2.5 ms (variation due to factors explained in Section 4) and hence our system requires no prediction algorithm in most cases. We have conducted road demonstrations while traveling at usual traffic speeds to show the feasibility and effectiveness of the design (see website for videos [25]). Example applications include anti-glare persistent high beams, visibility improvement in snowstorms (shown with artificial snow), and illuminating roads with better contrast and lane definition. Results of providing early visual warning of obstacles can be seen at [25]. Our system is able to tackle all of these applications with a single hardware design and achieve higher light throughput than what is possible with any configuration of a small number of controllable LEDs available in current headlights.

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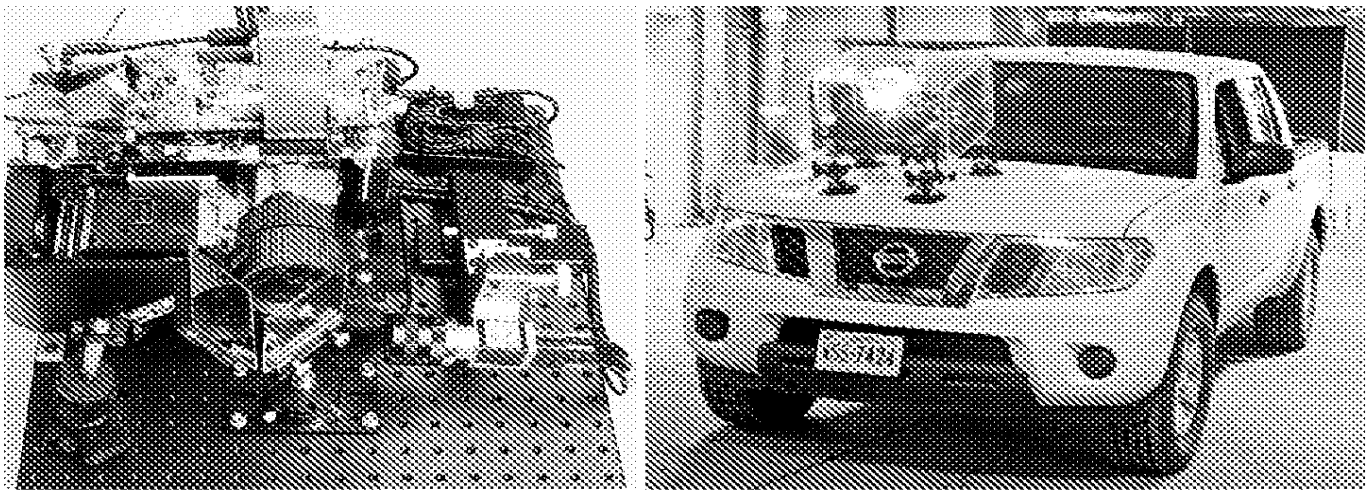


Fig. 1. Left: Prototype of our programmable automotive headlight design (computer not pictured). The camera, spatial light modulator, and beam splitter are firmly mounted to an optical breadboard. A mirror to the side of the beam splitter deflects reflected light from the light source upward. Right: Road tests were conducted by securing the prototype to the hood of a vehicle with a suction cup-based mount. An acrylic enclosure was constructed to protect components from dust, dirt, and moisture.

2 Overview of Programmable Headlight Design

Our programmable headlight design consists of four main components: an image sensor, processing unit, spatial light modulator (SLM), and beam splitter. The *imaging sensor* observes the road environment in front of the vehicle. Additional sensors such as RADAR or LIDAR can be incorporated into the design to complement the camera. The *processor* analyzes image data from the sensor and controls the headlight beam via a spatial light modulator. The *spatial light modulator* (e.g., digital micro-mirror device, liquid crystal display, liquid crystal on silicon, etc.) modifies the beam from a light source by varying the intensity over space and time in two dimensions. We use a DMD because its high working frequency and small pixel size permit high-speed modulation and fine illumination control, which makes it possible for our headlight to quickly react to objects as small as snowflakes and objects as large as vehicles.

The camera and SLM are co-located along the same optical line of sight via a *beam splitter*, which virtually places the image sensor and DMD at the same location. Co-location is advantageous because it makes calculating the distance to objects unnecessary. Consequently, there is no need to perform costly computations required for depth estimation and 3D tracking. Also, a single homography will map the camera and projector image planes regardless of the scene. If the image sensor and DMD chip are placed very close to each other, the beam splitter is not required. Reactive visual systems with a similar design have been described by [11], [16], [20], but their systems are too slow for high-speed automotive applications. High latency in conjunction with road effects like wind turbulence and vibration will require complex prediction algorithms that will add latency to the system making it unusable.

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3 Design and Implementation of a Prototype System

We designed and implemented a prototype with low latency and high data throughput (Figure 1), and conducted road tests to demonstrate the feasibility of our DMD-based reactive visual system design as a headlight. The camera and SLM must have a very fast frame rate, e.g., kilohertz range, to capture images of fast moving objects and to create illumination patterns that are imperceptible to drivers. Consequently, a lot of data must be transferred to and from the processing unit with minimal latency. To achieve these goals, components with high-speed interfaces were tightly integrated through hardware and software. The prototype measures 45 cm wide, 45 cm long, and 30 cm tall and is currently too large to install in a vehicle as a headlight. The current size is due to using off-the-shelf components. Specialized embedded hardware with an integrated imaging, processing, and SLM unit will be required to create a compact headlight. Road tests were conducted by securing the prototype to the hood of a vehicle with a suction-cup based vehicle mount. A custom acrylic enclosure protects the system from dust, dirt, and moisture. We demonstrate in Sections 5 and 6 that the prototype performs a variety of tasks at typical traffic speeds.

3.1 Sensing the Road Environment

A camera (Basler acA2040) with a CMOS sensor highly sensitive to light with correlated double sampling to significantly reduce noise was used to capture images. The camera is sensitive to visible and near infrared light since most objects of interest are detectable within this spectrum of light. Monochrome imagery is used to avoid the computational overhead associated with demosaicing the Bayer pattern. A global shutter with area scan is used to avoid distortion effects common with the rolling shutter. Latency is reduced via a pipelined pixel architecture that permits exposure during readout. The camera's extended CameraLink configuration has transfer rates of up to 6.8 gigabits per second. The camera is mounted to a set of linear stages for fine control during calibration.

3.2 Image Processing and System Control

A desktop computer provides an interface between the camera and SLM, performs image analysis, and controls the system. The computer was custom built using an Intel Core 3.4 GHz (i7-2600K) CPU with eight cores and hyper-threading technology. A PCI express 2.0 frame grabber (Bitflow Karbon SP) that transfers image data directly into computer memory without any buffering. The main processing tasks were parallelized to reduce latency and increase system responsiveness. The three-stage processing pipeline is shown in a timing diagram (Figure 2) with times measured from the prototype system as described in Section 4. Capture refers to the integration time of the camera. TX denotes the time to transfer image data to the host computer and the time to transfer data from the host computer to the SLM. Process refers to image analysis and system control. Illumination refers to directing light to the scene for a single cycle.

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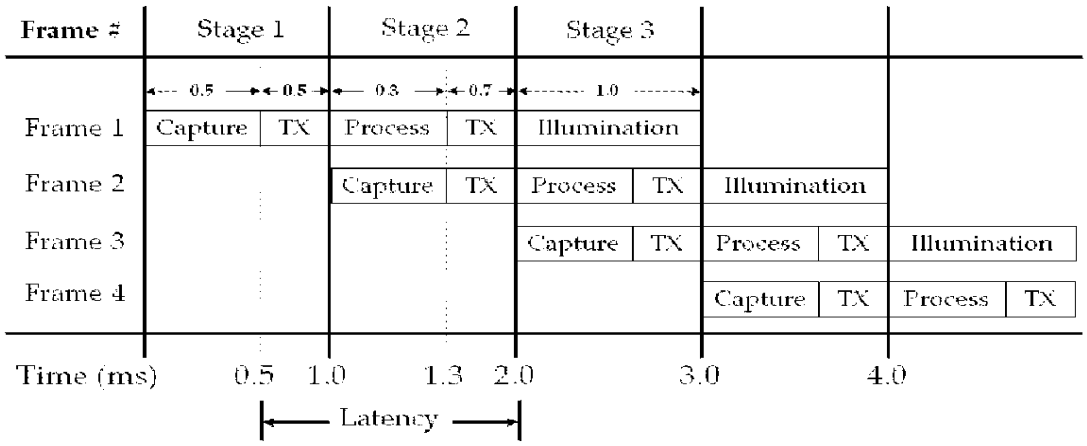


Fig. 2. Timing diagram of the three-stage pipeline with execution times in milliseconds. Capture refers to camera exposure. Process refers to analysis of images and system control. TX denotes data transfer between camera and computer or between computer and SLM. Latency is the time required to illuminate the scene after capturing an image.

Since execution time is critical, the focus of image analysis algorithms is on speed rather than accuracy. Image analyses were performed using OpenCV compiled with Intel Integrated Performance Primitives and Thread Building Blocks to maximize parallelism. Functions that perform per-pixel operations were combined using SSE2 intrinsic functions, when possible, to reduce the computation time associated with multiple iterations over the image. Pre-computable operations such as distortion correction and perspective transformation were initialized and stored in look-up tables. After analyzing images, illumination patterns are encoded and stored in an array then transmitted to the SLM.

3.3 High-Speed Illumination of the Road Environment

A DMD chip is used as a SLM for its spatial and temporal resolution. They are used in consumer DLP projectors, but are driven by video frame rates, which are well below our kilohertz target. A DLP development kit (WinTech W4100) based on the Discovery 4100 (Texas Instruments) was used as the basis of our SLM because the board contains a user programmable FPGA (Xilinx Virtex-5) to achieve fast update rates. The DMD chip is 0.7" with XGA (1024×768) resolution, which, essentially means the headlight beam can be divided into 786,432 smaller beams each of which can be turned on or off. This type of modulation gives unprecedented control over the illumination in space and time. Illumination patterns are received from the host computer by USB 2.0.

The DLP development kit does not include any optics. The optics and light source from a consumer DLP projector (InFocus IN3124) were used instead of designing custom components. We chose this projector because it uses the same DMD chipset as the development kit and uses a lamp brighter (4800 Lumens) than most vehicle high beams. The projector's native DMD chip was removed from the optics module and replaced with that of the development kit via a

custom machined mount. A copper heat sink and fan were installed to improve heat dissipation. All of the native DLP electronic boards were left attached to maintain operability even though only the optics and lamp are actively used.

The FPGA was programmed to display patterns faster than 1 kHz. In our design, the FPGA receives data streamed from the host PC and produces the commands for a DMD controller to display the appropriate patterns on the DMD. Each row (1024 pixels) of the DMD is represented as a bit-vector. Transferring a 1024-bit vector for each of the 768 rows was too slow (over 1.5 ms). Instead, the rows are subsampled by a factor of four by representing 1024 pixels by a 256-bit vector. Some resolution is lost, but the visual impact is negligible. Data was further compressed to increase system speed by reading out every other row from the image sensor. The missing rows of the resulting illumination pattern are filled-in by duplicating the previous row on the FPGA. Thus, the image is down-sampled by a factor of 4 horizontally and a factor of 2 vertically.

3.4 System Calibration

Calibrating the system consists of co-locating the camera and SLM, and computing the homography between the camera and SLM image planes. To achieve co-location, a beam splitter with 50% transmission and 50% reflection (Edmund Optics) is used. The projector, rigidly affixed to the optical breadboard, illuminates an object. The camera is translated in all three cardinal directions and rotated until shadows cast by the object are no longer observed by the camera. This recursive co-location procedure takes about 10 minutes to perform.

After positioning the camera and SLM along the same optical line of sight, a perspective transform is calculated for the homography. Radial and tangential distortion by the camera lens is characterized by capturing an image of a checkerboard image and estimating the camera's intrinsic parameters and distortion coefficients. A homography is computed by first projecting a checkerboard pattern and capturing an image. The image is then undistorted and detected corner points are used to compute a perspective transform. After performing these calibration steps, the transformations are stored in look-up tables for later use and the system can be used anywhere without modification. These calibration steps were performed using functionality available in the OpenCV library.

4 Measuring System Latency

As discussed in Section 3.2, the system is pipelined in three stages: image capture and transfer, image processing and transfer, and illumination. Latency of the system is the time between capturing an image and illuminating the scene. There are several factors that contribute to latency. Image size is directly related to camera/computer and computer/SLM transfer time, and image processing time. The size and number of detected objects also has an effect on latency requiring more processing time and thus increases latency. Lastly, the computer's operating system has timing jitter and interrupts that add uncertainty to the latency.

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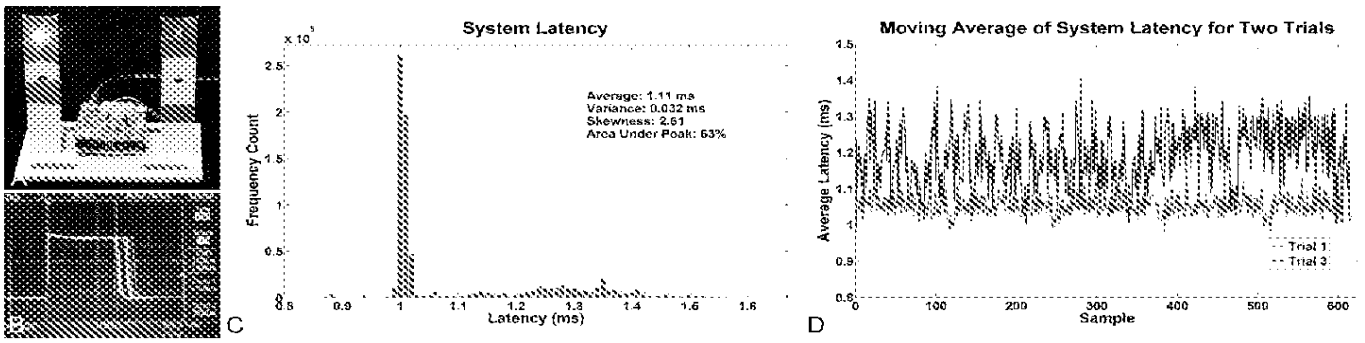


Fig. 3. A: Circuit for measuring system latency consists of an LED and a phototransistor connected to a micro-controller board (Arduino Uno). To measure the system's reaction time, the micro-controller measures the time for the system to detect the illuminated LED then illuminates/dis-illuminates the phototransistor. B: Latency is observed on an oscilloscope (typical readout shown) and measured/recorded by the micro-controller board. C: Histogram (0.01 ms per bin) shows data collected over 30 minutes. The system has some uncertainty, but typically reacts within about 1 ms. D: Moving average (1 second intervals) of latency for a trial with and without uncertainty.

To measure system latency, a circuit was built to measure the system's time to react to an illuminated LED (Figure 3A). The circuit consists of an LED, phototransistor, and micro-controller (Arduino Uno). The high-level idea is to measure the response time of the system by enabling an LED and timing how long it takes for the system to detect the LED and project light onto the phototransistor. To achieve this, the system was programmed to illuminate the phototransistor every other frame. Observing the signal from the phototransistor with an oscilloscope reveals a step response as shown in Figure 3B. The plateau of the signal corresponds to the time that the phototransistor is illuminated. Time was measured with microsecond precision and recorded with the micro-controller.

Data were collected for thirty minutes evenly divided over six separate trials to assess repeatability. During these trials, the image resolution was 800×220, exposure time was 750 μs, and frame rate was 1 kHz. Latency for all the trials is shown in Figure 3C. Across the six trials, the system most often reacts within 1 ms and 63% of the time reacts within two standard deviations from the peak. The average reaction time for all six trials was 1.11 ms with a variance of 0.032 ms. The histogram also reveals uncertainty in the system. This variability was studied by averaging every 1 second worth of data. Shown in Figure 3D are averaged data for two trials: one trial with little variability and one trial with a lot of variability. The plot shows that, in either situation, latency consistently varies by small fluctuations within a narrow band. In the worst case, the fluctuations range from 1 to 1.4 ms.

Several strategies can be utilized to account for latency variability. The uncertainty can be simply included in the illumination pattern by artificially increasing the size of detected objects. Light throughput will decrease, but accuracy will improve. Alternatively, temporal information can be used to predict the location of detected objects. Care must be taken to ensure the prediction model

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does not add too much time to the system's latency. At high frame rates, a linear model will suffice for most applications. The time to perform processing tasks was measured, in software, with a high resolution timer (Windows API). The average time for processing was 0.3 ms with a standard deviation of 0.04 ms (Figure 2). The time to send data to the DMD board over USB was measured for 5 minutes with an average of 0.76 ms and a standard deviation of 0.07 ms.

5 Anti-Glare High Beams

Glare from the headlights, especially high beams, of oncoming vehicles cause significant stress and distraction at best and temporary blindness at worst. Trucks and other vehicles with headlights at high positions are the worst offenders. Although, glare is not often reported as a cause of accidents, hundreds of fatal night crashes attribute glare as a contributing factor every year [15]. Glare is especially problematic for the elderly whom take eight times longer to recover from glare as compared to a 16-year old [13]. Although high beams are a nuisance to other drivers, they are beneficial on narrow, curvy, and poorly lit roads, especially in rural areas where wildlife routinely jumps onto the road.

Anti-glare headlights are currently being deployed by car companies, e.g., [21], [22], [23], [24]. The details of their systems are publicly unavailable, but it is known that these systems utilize multiple LEDs and sensors placed at different locations in the vehicle, e.g, [10], [9], [2]. Based on this information, it can be inferred that spatial resolution is limited to the number of LEDs. Camera frame rates of these headlight systems are limited to 30 - 60 Hz and thus have high latency [26], [27], [28]. In this section, it will be shown that a high-resolution SLM with low latency produces the best light throughput.

System Requirements and Comparisons. Computer simulations were performed to determine the latency required to maintain high light throughput. Camera parameters and the position of our prototype on a vehicle were used in simulations where two vehicles traveled towards each other at 225 kph on a two-lane, straight road. Detection and prediction were set to be error-free guaranteeing that only system latency contributed to light throughput. Light throughput was calculated for latencies of 2, 16, 30, 50, and 100 ms (Figure 4A). Throughput remains above 90% for all latencies tested when the vehicles are farther than 20 m apart. The reason for this is the oncoming vehicle is moving towards the camera and its position in the image has little variation. However, as the vehicles move closer towards each other, light throughput substantially decreases with higher latency. It is clear that the system needs a latency of at least 2 ms to maintain 90% light throughput when the vehicles are close to each other. The same would be true for vehicles in further lanes or on curved roads.

Computer simulations were conducted to compare the performance LED-based headlights to DMD-based headlights with the same latency. Since specific details of LED-based systems are publicly unavailable, several assumptions were made: (a) LEDs were positioned in a linear array parallel to the road and (b) all LEDs in the array that would illuminate the oncoming driver are disabled.

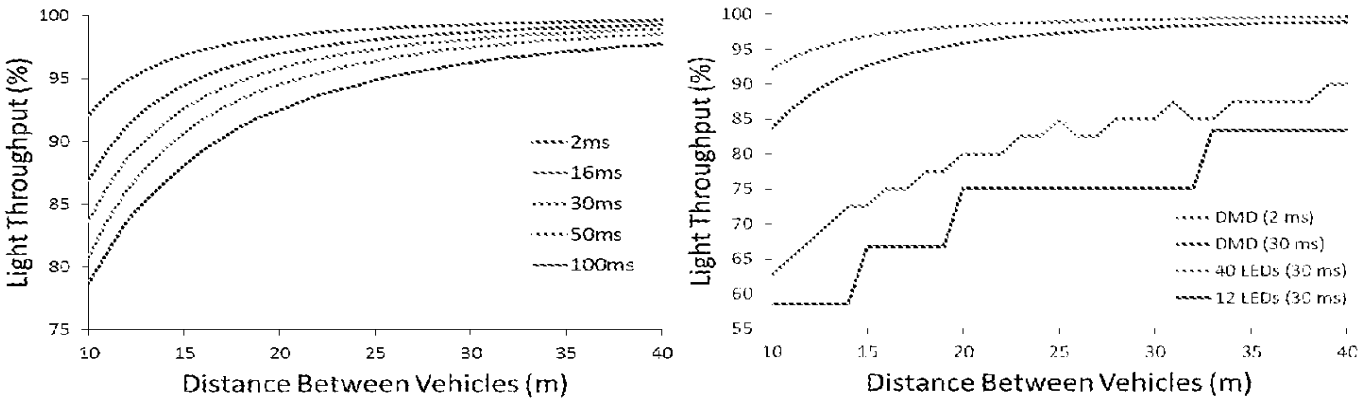


Fig. 4. Results of computer simulations of anti-glare headlights. Detection and prediction are assumed to be perfect and vehicles were traveling towards each other in adjacent lanes at a relative speed of 225 kph. Left: Light throughput as a function of distance between vehicles for different system latencies. Right: Light throughput for DMD- and LED- based anti-glare headlights for different latencies. Simulations show lower latency and higher resolution results in higher light throughput and accuracy, which will be even more relevant for curvy, multilane roads with multiple vehicles.

Simulation results are shown in Figure 4B along with those of the DMD-based system. The low spatial resolution of LED-based systems results in lower light throughput and also creates flicker (abrupt changes in light throughput) for the driver. The flicker can be reduced by turning off more LEDs, but with the trade-off of sacrificing light throughput.

Our Headlight Design as Anti-Glare High Beams. The anti-glare problem and our solution is illustrated in Figure 5A. Headlights from oncoming vehicles are detected in the captured image. Headlights are detected using the assumption that they are the brightest objects in the system's field of view. A very short exposure (100 μs) time is used and the image is thresholded. False detections can be reduced by excluding connected components that are too small to be headlights. Once the locations of the vehicles are known in the camera's reference frame, it is transformed to the headlight reference frame and the spatial light modulator blocks light in that direction. Since the resolution offered by the SLM is very high, only a small region above the detected headlight overlapping the oncoming driver's head is dis-illuminated. This type of beam blocking can be done for any number of oncoming drivers without significant loss of illumination. Compared to the system settings used to evaluate latency in Section 4, the image resolution was increased to 1000×340 to provide the largest field of view possible resulting in a system latency to 2.5 ms.

Demonstration on the Road. The system was tested on the road at night with three oncoming vehicles. Figures 5B-D show video frames captured from inside vehicles driving towards the programmable headlight. In Figure 5B, the blinding glare as the vehicles near each other is shown. Figure 5C and D show the benefit of our anti-glare headlight. Clearly, the difference in visibility is significant allowing drivers to see the road, vehicle, and surroundings. The prototype was able to function for all three drivers at the same time with little light loss.

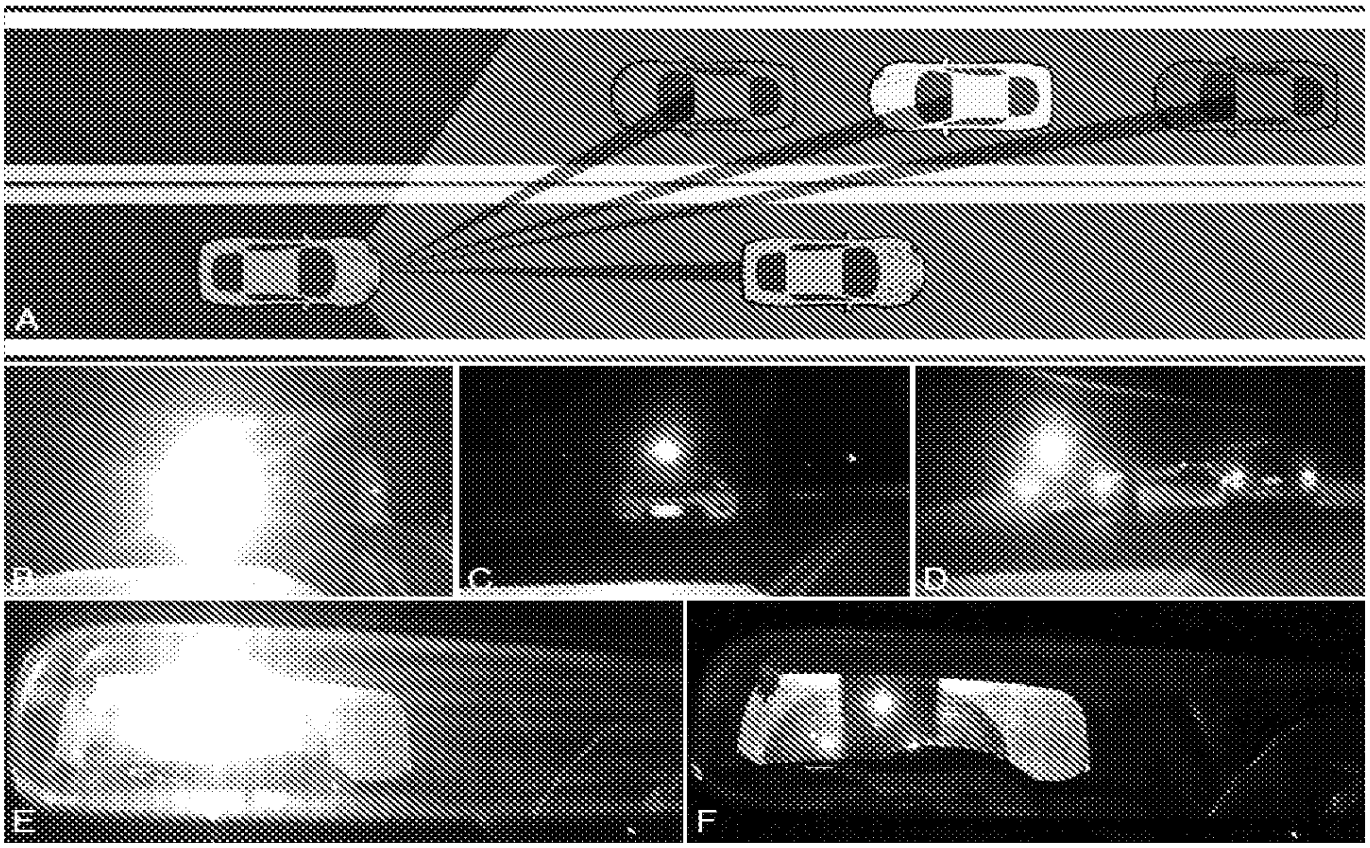


Fig. 5. A: Illustration for eliminating high beam glare. Vehicles are identified and small regions around drivers are dis-illuminated while maintaining illumination elsewhere. Drivers with programmable headlights can then potentially use high beams without worry. Middle row shows view while driving towards our prototype. B: Glare typically seen from high beams (anti-glare feature disabled). C: Reduced glare when the anti-glare feature of our headlight is enabled. D: Anti-glare headlights allow the driver to better see other vehicles on the road. E: Glare in a rear view mirror caused by a following vehicle. F: Tail lights are detected to avoid illuminating the rear-view mirror.



Fig. 6. View shown from the perspective of the vehicle equipped with our prototype. Left: Anti-glare feature is disabled acting as a typical high beam. Middle and Right: Anti-glare feature is enabled detecting multiple oncoming vehicles and reducing light only in the direction of each driver. Notice no discernable difference between images.

The average light throughput was calculated from saved images to be 93.8% with a standard deviation of 3.3%. In Figure 5F, tail lights were detected to avoid illuminating the driver's rear-view mirror and glaring them from behind. As shown in Figure 6, there is no discernible difference to the driver with the programmable headlight when the anti-glare function is enabled. The odd shape of the light beam is due to the system's position and the perspective of the capturing device. Installation in the headlight bay will create a more uniform shape and the spread of the light beam can be increased with a wide angle lens.

6 Demonstrating System Design Versatility

Thus far, computer simulations and demonstrations have shown that the proposed headlight design is advantageous to current anti-glare headlight designs. Our headlight can also be programmed to perform other tasks, whereas, other advanced lighting systems may require additional light sources, sensors, mechanical parts, etc., or are insufficient due to low spatial resolution or high latency. Here we show several tasks, such as visibility improvement in snowstorms (using artificial snow) and illuminating roads with better contrast and lane definition (visual warning of obstacles can be seen at [25]). Also shown is a computational photography application to examine high-speed events.

6.1 Improving Visibility During Snowstorms

Driving in a snowstorm at night is incredibly difficult and stressful. Snowflakes are illuminated brightly and distract the driver from observing the entire road. Researchers in computer vision have proposed methods for removing snow from videos [17], [18], [19]. Processed videos can be displayed for the driver, but current implementations are not intuitive and, at times, distracting for the driver. We can address this problem with a solution similar to that for anti-glare, i.e., reacting to detected bright objects. The main difference, however, is that the density, size, and speed of snowflakes requires high-resolution, low-latency illumination to be effective. Therefore, we exploit the high-resolution and fast illumination beam control of our prototype to distribute light between falling snowflakes to reduce backscatter directly in the driver's visual field (Figure 7). However, this application is significantly more challenging since (a) the size of snowflakes is very small compared to an easily detectable vehicle and (b) the quantity of snowflakes is several orders higher than the number of cars on the road. The goal is to send as much light as possible from the headlight to sufficiently illuminate the road for the driver while dis-illuminating snowflakes.

Computer simulations performed in [11] demonstrate that the idea is feasible. They estimate that, for a vehicle traveling at 30 kph, the system's latency needs to be 1.5 ms or less to have high light throughput and accuracy. We demonstrate improved visibility outside at night with artificial snowflakes. Snowflakes were detected by performing background subtraction and binary thresholding. To compensate for any small detection errors, dilation with a structuring element of

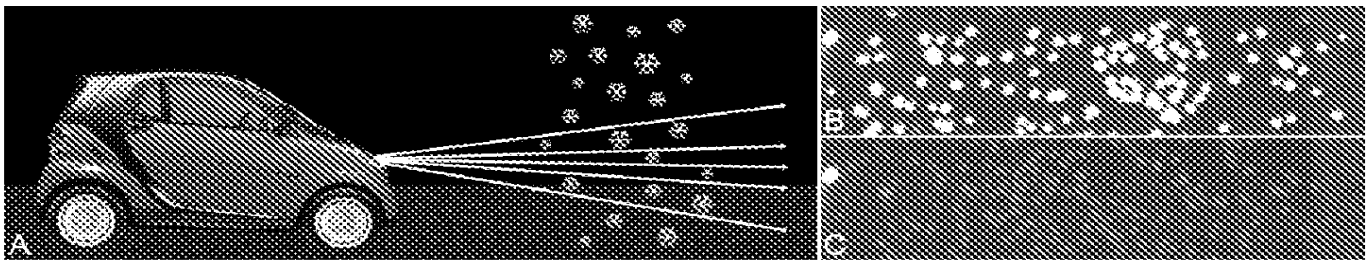


Fig. 7. A: Our headlight has unprecedented resolution over space and time so that beams of light may be sent in between the falling snow. Illustration adapted from [11]. B: Artificial snowflakes brightly illuminated by standard headlight. C: Our system avoids illuminating snowflakes making them much less visible.

a radius equivalent to that of a snowflake was applied. The visibility improvement can be seen by comparing Figures 7B and 7C. Even though the snowflakes fall chaotically, no prediction was required because of the system's fast speed. For comparison, the system by [11] (13 ms latency) was demonstrated for rain drops falling along a straight path and required a linear prediction model.

6.2 Improved Lane Illumination

Sometimes the road is not clearly visible and no amount of illumination from a standard headlight can assist the driver. A few examples of such situations are snow covered roads, roads without lane markings or shoulders, and poorly lit roads. Our prototype can be used to brightly illuminate only the driver's lane to provide them with a visual guide. Opposing lanes, curbs, and sidewalks can be dimly illuminated to create a strong contrast with the driver's lane and also provide sufficient illumination to see obstacles (Figure 8A). For this application, images do not need to be captured or analyzed, and objects do not need to be tracked. After computing the homography with the road plane, the headlight acts only as an illumination device. For proof-of-concept, illumination patterns were pre-determined for the stretch of road where experience were conducted. In practice, the position and speed of the vehicle will be used to dynamically determine the illumination patterns required for the road.

In Figure 8B, the driver's lane and lane markings are fully illuminated, and the adjacent lane is dimly illuminated. The same contrast is used while driving on a dark, unmarked road in Figure 8C. The opposing lane is dimly illuminated while the driver's lane remains fully illuminated creating a demarcation line for the driver to follow. Vehicles driving on the illuminated lane will experience disorienting illumination patterns because the system is calibrated to illuminate the road plane. Therefore, the beam can be adjusted where vehicles are detected in either lane as illustrated in Figure 8D. The adjacent lane can be illuminated up to the location of an oncoming vehicle while maintaining full illumination of the driver's own lane (Figure 8E). Illumination can be controlled in the presence of vehicles in both lanes as well (Figure 8F).

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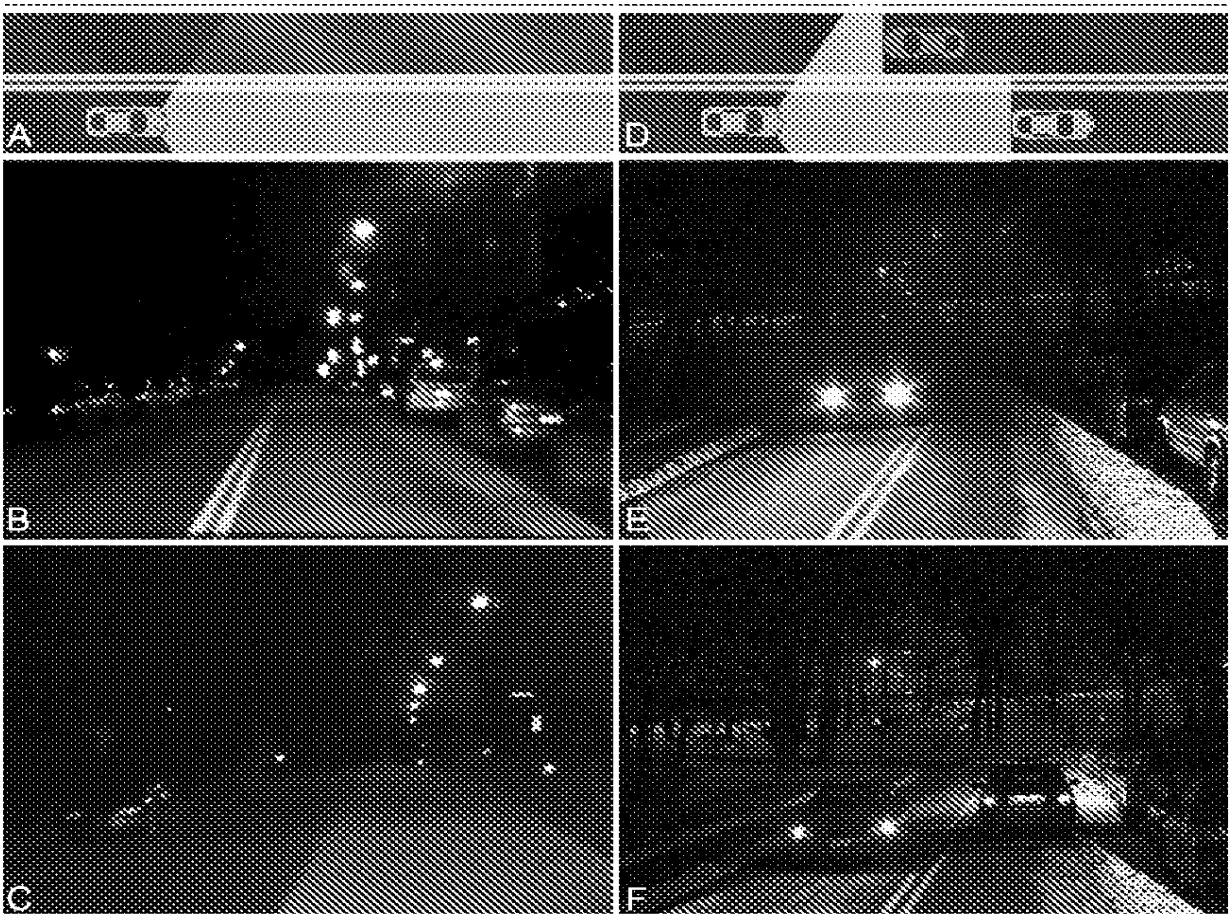


Fig. 8. A: Concept of illuminating the driver's lane with high-intensity light and illuminating the adjacent lane dimly to improve the contrast of the driver's lane. B: Driver's lane more brightly illuminated than the adjacent lane. C: Demonstration while driving on an unmarked road. D: Concept of adjusting lane illumination based on the presence of other vehicles. E: Illumination for the left lane stops at the oncoming driver to avoid projecting lane patterns on the vehicle. F: Lane illumination stops in front of the vehicle in the adjacent lane and behind the vehicle in the driver's lane.

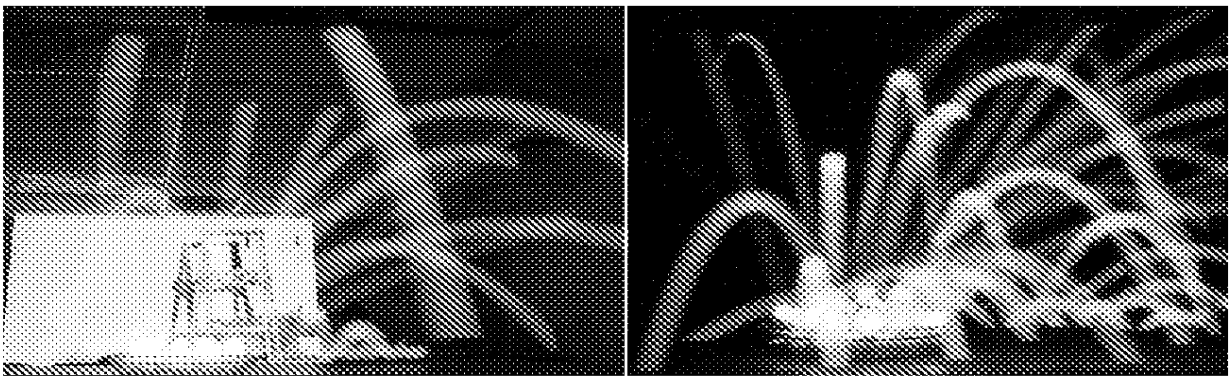


Fig. 9. A tennis ball is thrown into a bowl of ping pong balls causing them to fly through the air. A digital image was captured with a long exposure (3 seconds) to observe the trajectory of ping pong balls. Left: Image captured with scene brightly illuminated. Ball trajectories are not visible against the illuminated wall behind the scene. Right: Image captured with only the ping pong balls being illuminated. The trajectory of the balls is much more visible against the unlit background.

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6.3 Observing Events with Computational Photography

Generally speaking, our programmable headlight is a low-latency reactive visual system with many uses outside of the automotive field. It has the flexibility of illuminating or dis-illuminating any fast moving object. An interesting application is studying the trajectory of fast moving objects or fast events. Typically, to capture these types of images, an expensive camera is needed and the room needs to be brightly lit causing a decrease in contrast. Instead, with our system, only the objects of interest need to be illuminated.

For example, a handful of ping pong balls were placed in a bowl. A tennis ball was thrown into the bowl causing the ping pong balls to fly through the air. The ping pong balls were illuminated with infrared LEDs so that they would be detectable in the dark. To observe the trajectory of the ping pong balls, a long exposure (3 seconds) image was captured with a camera. The ping pong balls were detected and immediately illuminated. As shown in Figure 9, the trails are barely visible when the scene is fully illuminated, but are clearly visible when our system is used to illuminate just the ping pong balls.

7 Conclusions and Future Work

The automotive headlight should not be a passive device that can only be completely switched on or off. It should be capable of adapting to the environment to improve safety in poor visibility conditions. Moreover, the design for adaptive headlights should not be limited to a single task. It should be capable of performing many different tasks to help the driver in multiple road environments. Our headlight design provides unprecedented light beam control over space and time. We have demonstrated the flexibility of the headlight for numerous tasks: allowing drivers to use high beams without glaring any other driver on the road, allowing drivers to see better in snow, and allowing better illumination of road lanes, sidewalks and dividers. Our prototype can quickly react to the road environment within 1 to 2.5 milliseconds, and, thus does not create any flicker to be seen by the human eye. Further research and development is needed to make the prototype compact to fit within actual vehicle headlight compartments. Further engineering is required to make the system reliable in the presence of vehicular vibrations and heat. Lastly, more sophisticated algorithms and reliable software need to be developed before deploying our headlight design.

Acknowledgements. This research was funded in parts by a grant from the Intel Science and Technology Center for Embedded Computing, a grant from the U.S. Department of Transportation (Carnegie Mellon University Transportation Center (T-SET)), a gift from Ford Motor Company, a grant from the Office of Naval Research (N00014-11-1-0295), and an NSF CAREER Award (IIS-0643628). The authors also thank the NavLab group at Carnegie Mellon University, Robotics Institute for providing an experimental vehicle platform.

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Exhibit 4
NHTSA Proposed Rule 2018

DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Part 571

[Docket No. NHTSA–2018–0090]

RIN 2127–AL83

Federal Motor Vehicle Safety Standards; Lamps, Reflective Devices, and Associated Equipment

AGENCY: National Highway Traffic Safety Administration ("NHTSA"), Department of Transportation ("DOT").

ACTION: Notice of proposed rulemaking (NPRM).

SUMMARY: This document proposes amendments to Federal Motor Vehicle Safety Standard ("FMVSS") No. 108; *Lamps, reflective devices, and associated equipment,* to permit the certification of adaptive driving beam headlighting systems, if the manufacturer chooses to equip vehicles with these systems. Toyota Motor North America, Inc. (Toyota) petitioned NHTSA for rulemaking to amend FMVSS No. 108 to permit manufacturers the option of equipping vehicles with adaptive driving beam systems. NHTSA has granted Toyota's petition and proposes to establish appropriate performance requirements to ensure the safe introduction of adaptive driving beam headlighting systems if equipped on newly manufactured vehicles.

DATES: You should submit your comments early enough to be received not later than December 11, 2018.

ADDRESSES: You may submit comments to the docket number identified in the heading of this document by any of the following methods:

- *Federal eRulemaking Portal:* Go to *http://www.regulations.gov*. Follow the online instructions for submitting comments.
- *Mail:* Docket Management Facility: U.S. Department of Transportation, 1200 New Jersey Avenue SE, West Building Ground Floor, Room W12–140, Washington, DC 20590–0001.
- *Hand Delivery or Courier:* 1200 New Jersey Avenue SE, West Building Ground Floor, Room W12–140, between 9 a.m. and 5 p.m. ET, Monday through Friday, except Federal holidays.
- *Fax:* 202–493–2251.

Instructions: All submissions must include the agency name and docket number. *Note:* All comments received will be posted without change to *http://www.regulations.gov,* including any personal information provided. Please see the Privacy Act discussion below. We will consider all comments received before the close of business on the comment closing date indicated above. To the extent possible, we will also consider comments filed after the closing date.

Docket: For access to the docket to read background documents or comments received, go to *http://www.regulations.gov* at any time or to 1200 New Jersey Avenue SE, West Building Ground Floor, Room W12–140, Washington, DC 20590, between 9 a.m. and 5 p.m., Monday through Friday, except Federal Holidays. Telephone: 202–366–9826.

Privacy Act: Anyone is able to search the electronic form of all comments received into any of our dockets by the name of the individual submitting the comment (or signing the comment, if submitted on behalf of an association, business, labor union, etc.). You may review DOT's complete Privacy Act Statement in the **Federal Register** published on April 11, 2000 (Volume 65, Number 70; Pages 19477–78) or you may visit *http://www.dot.gov/privacy.html*.

Confidential Business Information: If you wish to submit any information under a claim of confidentiality, you should submit three copies of your complete submission, including the information you claim to be confidential business information, to the Chief Counsel, NHTSA, at the address given under **FOR FURTHER INFORMATION CONTACT**. In addition, you should submit two copies, from which you have deleted the claimed confidential business information, to Docket Management at the address given above. When you send a comment containing information claimed to be confidential business information, you should include a cover letter setting forth the information specified in our confidential business information regulation (49 CFR part 512).

FOR FURTHER INFORMATION CONTACT: Please contact Mr. Markus Price, 202–366–0098 or Mr. John Piazza, Office of Chief Counsel, Telephone: 202–366–2992. Facsimile: 202–366–3820. You may send mail to these officials at: The National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE, Washington, DC, 20590.

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I. Executive Summary

Glare, Visibility, and Adaptive Driving Beam Technology

This proposal is intended to allow an advanced type of headlighting system referred to as adaptive driving beam to be introduced in the United States. Adaptive driving beam ("ADB") headlamps use advanced technology that actively modifies the headlamp beams to provide more illumination while not glaring other vehicles. The requirements proposed today are intended to amend the existing regulations to permit this technology and ensure that it operates safely.

Vehicle headlamps must satisfy two different safety needs: Visibility and glare prevention. The primary function of headlamps is to provide forward visibility. At the same time, there is a risk that intense headlamp illumination may be directed towards oncoming or preceding vehicles. Such illumination, referred to as glare, can reduce the ability of other drivers to see and cause discomfort. Headlighting has therefore traditionally entailed a trade-off between long-distance visibility and glare. This is reflected in the requirement that headlamp systems have both lower and upper beams. The existing headlight requirements regulate

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the beam pattern (photometry) of the upper and lower beams; they ensure sufficient visibility by specifying minimum amounts of light in certain areas on and around the road and prevent glare by specifying maximum amounts of light in directions that correspond to where oncoming and preceding vehicles would be.

While the benefits of improved visibility and the harmful effects of glare are difficult to quantify, they are real. For example, a recent study from the Insurance Institute for Highway Safety found that pedestrian deaths in dark conditions increased 56% from 2009 to 2016. The harmful effects of glare are highlighted by the thousands of consumer complaints NHTSA has received from the public over the years, Congressional interest, and the Agency's research. NHTSA received more than 5,000 comments in response to a 2001 Request for Comments on glare from headlamps and other frontal vehicle lamps. Most of these comments concerned nighttime glare. In 2005, Congress directed the Department of Transportation to study the risks of glare. In response to these concerns, NHTSA initiated a multipronged research program to study the risks of, and possible solutions to, glare.

ADB systems are an advanced type of headlamp beam switching technology that provides increased illumination without increasing glare. Headlamp beam switching systems were first introduced in the 1950s, and while not initially widely adopted, have more recently become widely offered as optional equipment. These traditional beam switching systems switch automatically from the upper beam to the lower beam when meeting other vehicles. ADB systems improve on this technology. They utilize advanced equipment, including sensors (such as cameras), data processing software, and headlamp hardware (such as shutters or LED arrays). ADB systems detect oncoming and preceding vehicles and automatically adjust the headlamp beams to provide less light to the occupied roadway and more light to the unoccupied roadway.

ADB technology enhances safety in two ways. First, it provides a variable, enhanced lower beam pattern that is sculpted to traffic on the road, rather than just one static lower beam pattern. It provides more illumination than existing lower beams without glaring other motorists (if operating correctly). Second, it likely will lead to increased upper beam usage. Research has shown that most drivers under-utilize the upper beams. The effects of this increase as speeds increase, because at higher speeds the need for greater seeing distance increases. ADB technology (like traditional beam switching technology) enables the driver to activate the ADB system so that it is always in use and there is no need to switch between lower beams and upper beams. In this way, the upper beam will be more widely used, and used only when there are no other vehicles present. For both these reasons, ADB has the potential to reduce the risk of crashes by increasing visibility without increasing glare. In particular, it offers potentially significant safety benefits in avoiding collisions with pedestrians, cyclists, animals, and roadside objects.

ADB systems are currently available in foreign markets but are not currently offered on vehicles in the United States. ADB systems have been permitted (and regulated) in Europe for several years. ADB systems are not, however, currently offered on vehicles in the United States. NHTSA's lighting standard, Federal Motor Vehicle Safety Standard ("FMVSS") No. 108, has been viewed as not permitting ADB. In particular, the current lower beam photometry requirements do not appear to allow the enhanced beam that ADB systems provide. In 2013, Toyota petitioned NHTSA for rulemaking to amend FMVSS No. 108 to permit the introduction of ADB. SAE (formerly, the Society of Automotive Engineers) in 2016 published a recommended practice for ADB. And more recently, NHTSA has received multiple exemption petitions for ADB-equipped vehicles. NHTSA has granted Toyota's rulemaking petition and this proposal is our action on that grant.

The Proposed Requirements and Test Procedures

This proposal, if adopted, would amend the lighting standard to allow ADB systems on vehicles in the United States and ensure that they operate safely. ADB, like other headlamp technologies, implicates the twin safety needs of glare prevention and visibility. This proposal does three main things that, taken together, are intended to allow ADB systems and ensure that they meet these safety needs.

First, it would amend FMVSS No. 108 to allow ADB systems. We propose amendments to, among other things, the existing lower beam photometry requirements so that ADB technology is permitted.

Second, it proposes requirements to ensure that ADB systems operate safely and do not glare other motorists. ADB systems provide an enhanced lower beam that provides more illumination than the currently-allowed lower beam. If ADB systems do not accurately detect other vehicles on the road and shade them accordingly, other motorists will be glared. NHTSA is sensitive to concerns about glare due to the numerous complaints from the public that it has received, the 2005 Congressional mandate, and its own research. The proposal addresses this safety need with a combination of vehicle-level track tests and equipment-level laboratory testing requirements.

The centerpiece of the proposal is a vehicle-level track test to evaluate ADB performance in recognizing and not glaring other vehicles. We propose evaluating ADB performance in a variety of different types of interactions with either an oncoming or preceding vehicle (referred to as a "stimulus" vehicle because it stimulates a response from the ADB system). The stimulus vehicle would be equipped with sensors near the driver's eyes (or rearview mirrors) to measure the illuminance from the ADB headlights. We propose a variety of different scenarios that vary the road geometry (straight or curved); vehicle speeds (from 0 to 70 mph); and vehicle orientation (whether the stimulus vehicle is oncoming or preceding). The illumination cast on the stimulus vehicle would be measured and recorded throughout the test run. In order to evaluate ADB performance, we are proposing a set of glare limits. These are numeric illuminance values that would be the maximum illuminance the ADB system would be permitted to cast on the stimulus vehicle. The proposed glare limits and test procedures are based on extensive Agency research and testing. NHTSA sponsored a study that developed the glare limits that are the objective performance criteria we are proposing. NHTSA also ran extensive track tests using vehicles equipped with ECE-approved ADB systems (modified to produce U.S.-compliant beams) to develop the test procedures and scenarios. The resulting performance requirements and test procedures are intended to ensure that an ADB system is capable of correctly detecting oncoming and preceding vehicles and not glaring them.

In addition to this track test, we also propose a limited set of equipment-level laboratory-tested performance requirements to regulate glare. We propose to require that the part of the adaptive beam that is cast near other vehicles not exceed the current low beam maxima, and the part of the adaptive beam that is cast onto unoccupied roadway not exceed the current upper beam maxima. These would essentially subject the ADB system to laboratory tests of the beam

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similar to what are currently required for headlights.

Third, it proposes a limited set of equipment-level laboratory-tested performance requirements to ensure that the ADB system provides sufficient visibility for the driver. The current headlamp requirements include minimum levels of illumination to ensure that the driver has a minimum level of visibility. We propose that these existing laboratory photometry tests be applied to the ADB system to ensure that the ADB beam pattern, although dynamically changing, always provides at least a minimum level of light. We propose requiring that the part of the adaptive beam that is cast near other vehicles comply with the current lower beam minima and that the part of the adaptive beam that is cast onto unoccupied roadway comply with the upper beam minima. These minimum levels of illuminance are in a direction such that they do not glare other motorists.

Regulatory Alternatives Considered: ECE Requirements and SAE J3069

NHTSA has considered a number of alternatives to this proposal. The main alternatives are the European requirements and the SAE recommended practice for ADB published in June 2016 (SAE J3069). This proposal incorporates elements of these standards, but departs from them in significant ways.

ECE Requirements

The Economic Commission for Europe (ECE) has permitted and regulated ADB under its type approval framework for several years. The ECE regulations have a variety of requirements that specifically apply to ADB. Many of these are equipment requirements that are not appropriate for a performance-oriented FMVSS. The ECE requirements also include a vehicle-level road test on public roads. The road test includes a variety of types of roads (*e.g.,* rural, urban) and types of interactions with other vehicles. The performance of the ADB system—with respect to both visibility and glare—is evaluated by the type approval engineer driving the ADB-equipped vehicle. A Federal Motor Vehicle Safety Standard is, however, statutorily required to be objective. The ECE road test is not appropriate for adoption as an FMVSS because it does not provide sufficiently objective performance criteria. The proposed track test scenarios are based, in part, on the ECE scenarios. The proposed glare limits are the objective criteria that we propose using to evaluate the performance of an ADB system as it is put through these maneuvers. In developing the proposal NHTSA tested several ADB-equipped vehicles that were type-approved to the ECE requirements. We believe that these ADB systems would able to meet the proposed requirements and test procedures.

SAE J3069

SAE published this recommended practice in June 2016, while NHTSA was developing this proposal, but after NHTSA had concluded the testing on which the proposal is based. The SAE standard is based, in part, on NHTSA's testing and research. SAE J3069 includes vehicle-level track testing as well as equipment-level laboratory testing requirements, although they differ from the proposal in important ways.

SAE J3069 sets out requirements and test procedures to evaluate ADB performance in recognizing and not glaring other vehicles. The major component of these is a vehicle-level track test for glare. The track test uses glare limits similar to (and based on) the ones developed by NHTSA. The track test, however, differs significantly from the proposed track test. The SAE test does not use actual vehicles to stimulate the ADB system, but instead uses test fixtures fitted with lamps that are intended to simulate oncoming and preceding vehicles. It also specifies a much smaller range of scenarios (for example, it only tests on straight roadway, not curves) and measures ADB illuminance only at a small number of specified distance intervals.

To test for glare SAE J3069 also includes, in addition to this track test, an equipment-level laboratory test requirement that the part of the adaptive beam directed towards an oncoming or preceding vehicle not exceed the lower beam photometric maxima. We propose a requirement very similar to this, but we also propose to require that the part of the adaptive beam directed towards unoccupied roadway not exceed the current upper beam maxima. Although this is not included in the SAE standard, we believe it is important to maintain the upper beam maxima because they too play a role in glare prevention.

To test for adequate visibility, SAE J3069 includes an equipment-level laboratory test requirement that the part of the adaptive beam directed towards unoccupied roadway comply with the lower beam minima. The proposed requirements are more stringent. They would require that this part of the adaptive beam comply with the current upper beam minima, not the lower beam minima. We believe this additional light is important. The proposal would also require that the part of the adaptive beam directed towards an oncoming or preceding vehicle meet the current lower beam minima. We believe this minimum level of illumination will ensure a minimum level of visibility (as explained above, we would also subject the dimmed portion of the adaptive beam to the lower beam maxima to ensure that the level of light is not so high as to glare other motorists).

II. Background and Safety Need

This proposal is intended to facilitate the introduction of an advanced headlighting technology referred to as adaptive driving beam ("ADB") into vehicles sold in the United States. ADB technology is an advanced type of semiautomatic headlamp beam switching technology. More rudimentary beam switching technology was first introduced in the 1950s and was limited simply to switching between upper and lower beams. Adaptive driving beam technology is more advanced. It uses advanced sensors and computing technology that more accurately and precisely detect the presence and location of other vehicles and shape the headlamp beams to provide enhanced illumination of unoccupied portions of the road and avoid glaring other vehicles.

This proposal would amend the Federal safety standard for lighting to permit the certification of this advanced technology and specify performance requirements and compliance test procedures for these optional systems. The proposed requirements are intended to ensure that ADB systems operate safely by providing adequate visibility while not glaring oncoming or preceding vehicles. To understand what the new technology does and the proposed regulatory adjustments, it will be helpful first to provide some background on headlamp technology and NHTSA's headlamp regulations.

The Twin Safety Needs of Glare Prevention and Visibility

Vehicle headlamps must satisfy two different safety needs: Visibility and glare prevention. Headlamps provide forward visibility (and also work in conjunction with parking lamps on passenger cars and other narrow vehicles to provide conspicuity). They also have the potential to glare other motorists and road users. For this reason, headlighting systems include a lower beam and an upper beam. Lower beams (also referred to as passing beams or dipped beams) illuminate the road and its environs close ahead of the

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vehicle and are intended for use during low speed driving or when meeting or closely following another vehicle. Upper beams (also referred to as high beams, main beams, or driving beams) are intended primarily for distance illumination and for use when not meeting or closely following another vehicle. The lower beam pattern is designed to produce relatively high levels of light only in the close-in forward visibility region; the upper beam is designed to produce high light levels in close-in and longer distance regions. Thus, headlighting has traditionally entailed a trade-off between forward longer-distance visibility for the driver and glare to other road users.

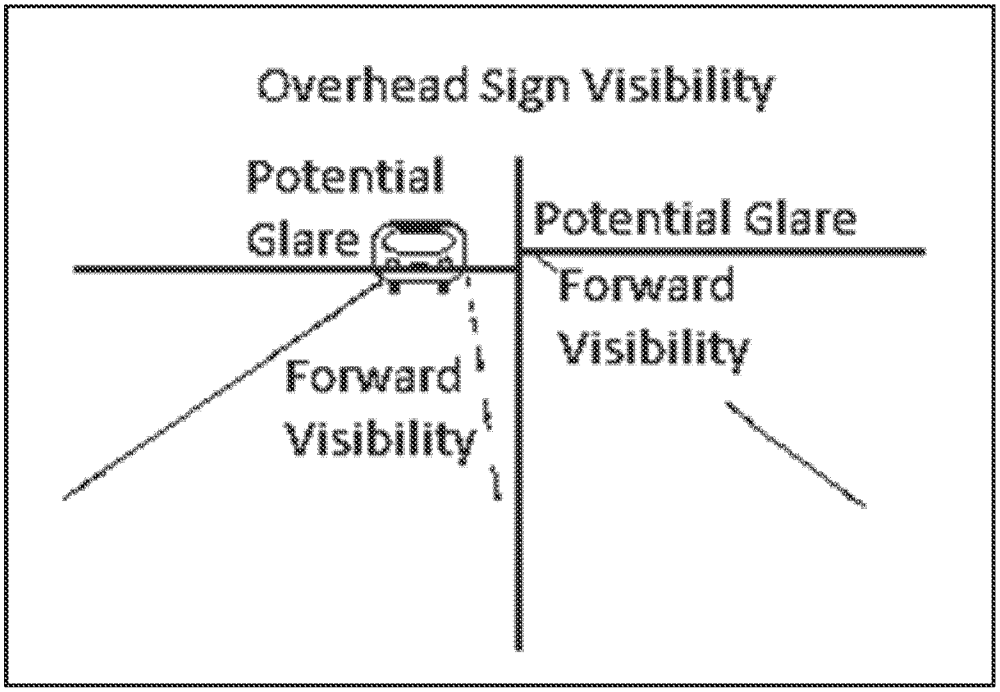


Figure 1.

Regions where one's own headlamps are likely to contribute to visibility and to glare to oncoming drivers.

Visibility and glare are both related to motor vehicle safety. Visibility has an obvious, intuitive relation to safety: The better a driver can see the road, the better he or she can react to road conditions and obstacles and avoid crashes. Although the qualitative connection to safety is intuitive, quantifying the effect of visibility on crash risk is difficult because of many confounding factors (for example, was the late-night crash because of diminished visibility or driver fatigue?). Glare, again intuitively, is related to safety because it degrades a driver's ability to see the forward roadway and any unexpected obstacles. Glare is a sensation caused by bright light in an observer's field of view. It reduces the ability to see and/or causes discomfort. Headlamp glare is the reduction in visibility and discomfort caused by viewing headlamps of oncoming or trailing vehicles (via the rearview or side mirrors).[1] Empirical evidence suggests that headlamp glare degrades important aspects of driving performance, such as decreasing the distance at which an object in or near the roadway can be seen, increasing driver reaction times, and reducing the probability a driver will detect an object.[2] It is difficult, however, to quantify the effect of glare on crash risk. Unlike drug or alcohol use, there is usually no way to determine precisely the amount of glare present in a crash. Nevertheless, some police crash reports mention glare as a potential cause, and it is reasonable to expect that reductions in visibility caused by headlamp glare increase crash risk.[3] Discomfort might also indirectly affect crash risk; for example, if a driver reacts to glare by changing her direction of gaze.[4] In addition to influencing safety, discomfort caused by glare may induce some drivers, particularly older drivers,

[1] *See generally* Nighttime Glare and Driving Performance, Report to Congress, p. ii (2007), National Highway Traffic Safety Administration, Department of Transportation [hereinafter "2007 Report to Congress"].

[2] 2007 Report to Congress, pp. iv, 11–14. *See also, e.g.,* John D. Bullough *et al.* 2003. An Investigation of Headlamp Glare: Intensity, Spectrum and Size. DOT HS 809 672. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration [hereinafter "Investigation of Headlamp Glare"], p. 1 ("It is almost always the case that headlamp glare reduces visual performance under driving conditions relative to the level of performance achievable without glare.").

[3] John D. Bullough *et al.* 2008. Nighttime Glare and Driving Performance: Research Findings, DOT HS 811 043. Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration, p. i–4.

[4] *Id.*, p. 33. *But see* Investigation of Headlamp Glare, p. 3 ("Very few studies have probed the interactions between discomfort and disability glare, or indeed any driving-performance related factors . . . .").

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to avoid driving at night or simply increase annoyance.[5]

The potential problems associated with glare are highlighted by the thousands of complaints NHTSA has received from the public on the issue. The introduction of halogen headlamp technology in the late 1970s and high-intensity discharge and auxiliary headlamps in the 1990s was accompanied by a marked upswing in the number of glare complaints to NHTSA. In response to increased consumer complaints about glare in the late 1990s, NHTSA published a Request for Comments in 2001 on issues related to glare from headlamps, fog lamps, driving lamps, and auxiliary headlamps.[6] NHTSA received more than 5,000 comments, most of which concerned nighttime glare from front-mounted lamps.[7]

This proposal is intended to enable the adoption of ADB and help ensure that ADB systems meet these twin safety needs of glare prevention and visibility.

Headlamp Photometric Requirements

NHTSA is authorized to issue FMVSS that set performance requirements for new motor vehicles and new items of motor vehicle equipment. Each FMVSS specifies performance requirements and test procedures the Agency will use to conduct compliance testing to confirm performance requirements are met. Motor vehicle and equipment manufacturers are required to self-certify that their products conform to all applicable FMVSS. FMVSS No. 108 specifies performance and equipment requirements for vehicle lighting, including headlamps. The standard requires, among other things, that vehicles be equipped with lower and upper beams as well as a means for switching between the two. Three aspects of these requirements are especially relevant to this proposal.

First, the standard sets out requirements for the beam performance (beam pattern) of the lower and upper beam. These requirements, referred to as photometric requirements, consist of sets of test points and corresponding criterion values. Each test point is defined with respect to an angular coordinate system relative to the headlamp. (As discussed in more detail below, these requirements are for an individual headlamp, not for an entire headlighting system as installed on a vehicle.) For each test point, the standard specifies the minimum amount of photometric intensity the headlamp must provide in the direction of that test point or the maximum level of intensity the headlamp may provide toward the test point, or both. There are different photometric requirements for lower beams and upper beams.[8]

Different test points regulate different aspects of headlamp performance. With respect to the lower beam, some test points ensure the beam is providing enough visibility of the roadway; other test points ensure the beam does not glare oncoming or preceding drivers; and other test points ensure there is illumination of overhead signs. The upper beam photometric test points primarily (but not exclusively) consist of minima, and ensure sufficient light is cast far down the road. The lower beam test points consist of both minima and maxima, resulting in a beam pattern providing more illumination to the right of the vehicle centerline and less illumination to the left side of the vehicle centerline and much less light above the horizon (roughly in the area of the beam pattern an oncoming vehicle would be exposed to). The lower beam test points controlling the amount of light cast on other vehicles are test points regulating glare. This rulemaking is related to and based on the current lower and upper beam photometric test points, especially the lower beam photometric test points limiting glare to oncoming and preceding drivers.

Second, the photometric requirements, and the requirements in FMVSS No. 108 generally, are requirements for equipment, not for vehicles. There are two basic types of Federal Motor Vehicle Safety Standards: Those establishing minimum performance levels for motor vehicles, and those establishing levels for individual items of motor vehicle equipment. An example of the former is Standard No. 208, Occupant Crash Protection. That standard requires that vehicles be equipped with specific occupant protection equipment (such as seat belts or air bags) and certified as being able to pass specified whole-vehicle tests (such as a frontal crash test). FMVSS No. 108, on the other hand, is largely an equipment standard. It uses a two-step process to regulate vehicle lighting. It requires vehicle lighting equipment be manufactured to conform to its requirements (such as the headlamp photometry requirements), whether used as original or replacement equipment. These requirements are, for the most part, independent of the vehicle; they regulate lamps as individual components, not as installed on a vehicle. It also requires lamps be placed within designated bounds on a motor vehicle. Thus, except for the type, number, activation, and location of lighting, FMVSS No. 108 primarily regulates lighting as equipment independent of the vehicle. The proposed glare limits and vehicle-level track test to evaluate ADB performance in recognizing and not glaring oncoming and preceding vehicles differ from the existing photometry requirements because they are vehicle-level—not equipment-level—requirements.

Third, compliance testing for conformance to the current photometry requirements is, for the most part, conducted in a laboratory. Photometry testing is performed under strictly controlled conditions in a darkened laboratory using highly accurate light measurement sensors. The headlamp being tested is placed in a specialized fixture, and the light sensor is used to measure the amount of light at each of the photometric test points to determine whether the headlamp complies with the photometric requirement(s) for that test point. The proposed vehicle-level track test to evaluate ADB performance differs from this traditional testing because it is track-based, not laboratory-based.

Regulatory History and Research Efforts Related to Glare

FMVSS No. 108 has included photometry requirements since the inception of the standard in 1967. The standard initially adopted SAE[9] photometry requirements.[10] Since then, NHTSA has made some adjustments to the photometry requirements. For example, the requirements were amended to permit brighter upper beams[11] and to include photometric test points for overhead retroreflective signs.[12] In addition, in the mid and late 1980s, NHTSA began to explore the possibility of making FMVSS No. 108 more of a vehicle standard.[13] NHTSA began developing vehicle-level headlamp photometric specifications based on the geometry of roadways, an analysis of crash data, and the driver's ability to see.[14] The Agency then issued an NPRM to amend the headlamp

[5] 2007 Report to Congress, p. iv.

[6] 66 FR 49594 (Sept. 28, 2001).

[7] 69 FR 54255 (Sept. 8, 2004).

[8] The upper beam photometric requirements are set out in Table XVIII; the lower beam photometric requirements are set out in Table XIX.

[9] The Society of Automotive Engineers (now SAE International). SAE is an organization that develops technical standards based on best practices.

[10] *See* 54 FR 20066 (May 9, 1989) (explaining history of photometric requirements).

[11] 43 FR 32416 (July 27, 1978).

[12] 58 FR 3856 (Jan. 12, 1993).

[13] 50 FR 42735 (Oct. 22, 1985) (Request for Comments).

[14] 52 FR 30393 (Aug. 14, 1987) (Request for Comments).

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requirements to make them more performance-oriented.[15] That rulemaking was terminated several years later because the technical complexities proved too difficult to surmount at that time.

NHTSA has also, at various times, taken steps to address problems and consumer complaints related to glare.[16] In the 1970s, NHTSA began research in response to consumer suggestions that vehicles should have a lower-intensity third beam for driving in well-lit areas. In the 1990s, NHTSA issued a final rule to address headlamp misaim, which is an important factor in the cause of glare.[17] In 2001, NHTSA published a Request for Comments concerning issues related to glare from headlamps, fog lamps, driving lamps, and auxiliary headlamps.[18] We observed that "auxiliary lamps are now becoming a source of complaint for glare. Often described as another set of headlamps, sometimes mounted lower, the public reports that these lamps seem to be used all the time at night. This documented misuse of fog lamps in particular helps substantiate the complaints that NHTSA has been receiving. NHTSA has received complaints about fog lamp use for a while, but never so many as recently."[19] NHTSA received more than 5,000 comments in response to the 2001 notice, most of which expressed concerns about glare. In 2005 Congress directed the Department of Transportation to conduct a study of the risks associated with glare to oncoming vehicles.[20] NHTSA also issued a variety of interpretation letters concerning the permissibility of various frontal lighting concepts. Generally, NHTSA allowed low-illuminance supplementary frontal lighting such as fog lamps, but found, in at least some instances, that higher-power frontal lamps were not permitted. These interpretations are discussed in detail in Section VI below which sets out NHTSA's tentative interpretation of how FMVSS No. 108 applies to ADB.

In response to the many complaints from the public about glare and the Congressional mandate to study the risks of glare, NHTSA initiated a multipronged research program to examine the reasons for the complaints as well as possible solutions. This effort culminated in several detailed Agency reports. For example, to better understand the complaints, NHTSA conducted a survey of U.S. drivers.[21] The results showed that while, for a majority of respondents (about 54%) glare was "noticeable but acceptable," a sizeable number of drivers (about 30%) rated glare as "disturbing." In 2003 NHTSA published a request for comments to learn more about advanced headlighting systems that can actively change the intensity and duration of headlamp illumination (these systems were precursors of ADB technology) to evaluate whether such systems would contribute to glare.[22] In 2007, NHTSA submitted a report on glare to Congress.[23] In addition, NHTSA conducted multiple studies, using field measurements, laboratory tests, computer analyses, and vehicle tests to examine the effects of different headlamp factors on driver performance.[24]

After these efforts concluded, NHTSA has continued in recent years to study the possibilities offered by advanced frontal lighting, including its potential to reduce glare. Two recent NHTSA research studies form the basis for this proposal. In 2012, the Agency published a study ("Feasibility Study")[25] exploring the feasibility of new approaches to regulating vehicle lighting performance, including headlamp photometry. Among other things, the study presented vehicle-based headlamp photometry requirements derived from the current requirements in Tables XVIII (upper beam) and XIX (lower beam). This included vehicle-based photometry requirements to ensure that other vehicles are not glared. NHTSA built on this effort by developing a vehicle-level track test to evaluate whether an ADB system complies with the derived photometry requirements for glare prevention ("ADB Test Report").[26] This research was necessary because, among other things, the current photometry requirements are equipment-based requirements that involve laboratory testing, not vehicle-based requirements tested on a track. Both of these research efforts are discussed in more detail in Section IV below.

Adaptive Driving Beam Technology, Toyota Petition for Rulemaking, and SAE J3069

The last several years have seen the development of ADB headlamps in other parts of the world, including Europe. Adaptive driving beam is a "long-range forward visibility light beam[ ] that adapts to the presence of opposing and preceding vehicles by modifying portions of the projected light in order to reduce glare to the drivers/riders of opposing and preceding vehicles."[27] It therefore has the potential to improve long-range visibility for the driver without glaring other road users.

ADB systems utilize advanced equipment, including sensors (such as cameras), data processing software, and headlamp hardware (such as shutters or LED arrays). ADB systems detect and identify illumination from the headlamps of oncoming vehicles and the taillamps of preceding vehicles. The system uses this information to automatically adjust the headlamp beams to provide less light to areas of the roadway occupied by other vehicles and more light to unoccupied portions of the road. ADB systems typically use the existing front headlamps with modifications that either implement a mechanical shade rotating in front of the headlamp beam to block part of the beam, or extinguish individual LEDs in headlamps using arrays of light source systems (*e.g.*, LED matrix systems). The portion of the beam directed to portions of the roadway occupied by other vehicles is at or even below levels of a traditional lower beam.[28] The portion of the beam directed at unoccupied portions of the road is typically equivalent to existing upper beams. The ADB systems NHTSA tested required that the driver manually select ADB mode using the headlighting system control and were designed to activate only at speeds above typical city driving speeds (about 20 mph).

ADB systems may be viewed as an advanced type of semiautomatic headlamp beam switching device (which is explicitly permitted as a compliance option in FMVSS No.

[15] 54 FR 20084 (May 9, 1989).

[16] *See generally* 66 FR 49594, 49596 (Sept. 28, 2001).

[17] 62 FR 10710 (Mar. 10, 1997).

[18] 66 FR 49594.

[19] 66 FR 49601.

[20] Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, Public Law 109–59, Sec. 2015 (2005).

[21] Perel & Singh. 2004. Drivers' Perceptions of Headlamp Glare from Oncoming and Following Vehicles, DOT HS 809 669. Washington, DC: National Highway Traffic Safety Administration.

[22] 68 FR 7101 (Feb. 12, 2003); 70 FR 40974 (July 15, 2005) (withdrawn).

[23] *See supra*, note 1.

[24] *See generally* Summary of Headlamp Research at NHTSA, DOT HS 811 006. Washington, DC: National Highway Traffic Safety Administration (2008).

[25] Michael J. Flannagan & John M. Sullivan. 2011. Feasibility of New Approaches for the Regulation of Motor Vehicle Lighting Performance. Washington, DC: National Highway Traffic Safety Administration. *See also* 77 FR 40843 (July 11, 2012) (request for comments on the report).

[26] Elizabeth Mazzae, G.H. Scott Baldwin, Adam Andrella, & Larry A. Smith. 2015. Adaptive Driving Beam Headlighting System Glare Assessment, DOT HS 812 174. Washington, DC: National Highway Traffic Safety Administration.

[27] SAE J3069 JUN2016, Sec. 3.1.

[28] SAE J3069JUN 2016, pp. 1–2.

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108 [29]). Semiautomatic beam switching was first introduced in vehicles in the 1950s, and while not initially widely adopted, in recent years it has become widely offered as optional equipment. Traditional semiautomatic beam switching headlamps switch automatically from upper beam to lower beam when meeting other vehicles. Unlike ADB, however, traditional semiautomatic beam switching headlamps are not able to vary the lower beam pattern to fit the traffic on the road; they are only able to produce a single lower beam pattern.

ADB technology enhances safety in two ways. First, it provides a variable, enhanced lower beam pattern that is sculpted to traffic on the road, rather than just the one static lower beam pattern. It is thus able to provide more illumination than existing lower beams. And it does this, if operating correctly, without glaring other motorists. Second, it likely will lead to increased, appropriate, upper beam usage (in situations where other vehicles will not be glared). Research has shown that most drivers under-utilize the upper beams. "[A]bundant evidence suggests that most drivers use lower beams primarily, if not exclusively." [30] Unfortunately, "driving with lower-beam headlamps can result in insufficient visibility for a number of driving situations," [31] particularly at higher speeds, because at higher speeds the need for greater seeing distance increases.[32] ADB technology (like traditional beam switching technology) enables the driver to activate the ADB system so that it is always in use, obviating the need to switch between lower and upper beams. In this way, the upper beam will be more widely used, and used only when there are no other vehicles present. For both these reasons, ADB has the potential to reduce the risk of crashes by increasing visibility without increasing glare. Although isolating the effect of visibility on nighttime crash risk is difficult because of many confounding factors, there is evidence suggesting diminished visibility likely increases the risk of crashes, particularly the risk of pedestrian crashes at higher speeds, as well as crashes involving animals, trains, and parked cars.[33]

ADB was first permitted in Europe by an amendment to R48 and R123 of the Economic Commission for Europe ("ECE"). Since then vehicle manufacturers have provided ADB systems in select vehicle lines sold in Europe. For instance, the 2017 Volkswagen Passat was available in Europe equipped with an ADB system. Audi has been installing ADB on a variety of Audi models and has sold (as of the end of 2016) approximately 123,000 vehicles with ADB across 55 different markets outside the United States.[34] Additional world regions adopting ECE regulations also permit ADB.

ECE lighting requirements permit adaptive driving beam systems under the umbrella of adaptive front lighting systems, including lighting devices type-approved according to ECE R123. These systems provide beams with differing characteristics for automatic adaptation to varying conditions of use of dipped-beam (lower beam) and if it applies, the main-beam (upper beam). ECE installation requirements for ADB systems take advantage of the type-approval framework used throughout ECE standards to test whole vehicles within traffic to verify performance. The system is evaluated subjectively through observations made by the type-approval technician during a test drive consisting of various driving situations.

The automotive industry has also recently developed a recommended practice for ADB technology. In June 2016, SAE adopted SAE J3069 JUN2016, Surface Vehicle Recommended Practice; Adaptive Driving Beam ("SAE J3069"). The standard, which is based, in part, on NHTSA's Feasibility Study, specifies a track test to evaluate the performance of ADB, as well as a variety of other requirements.

Although ADB has been deployed in Europe on a limited basis, it has not yet been deployed in the United States. This is largely because of industry uncertainty about whether FMVSS No. 108 allows ADB systems.[35] NHTSA has not, until this NPRM, issued an interpretation of whether and how FMVSS No. 108 applies to ADB. In 2013, Toyota petitioned NHTSA for rulemaking to amend FMVSS No. 108 to permit manufacturers the option of equipping vehicles with ADB systems.[36] In its petition, Toyota described how its system works, identified the potential safety benefits of the system, and discussed its view of how ADB should be treated under the Agency's regulations. In this NPRM, NHTSA sets out its tentative interpretation that the existing FMVSS No. 108 prohibits ADB, while, at the same time, granting and acting on Toyota's petition to amend the standard to allow for this technology and ensure that it meets the safety needs of glare prevention and visibility.

III. ECE ADB Regulations

ECE regulations allow ADB systems under the umbrella of adaptive front lighting systems ("AFS") under Regulation 48.[37] There are a variety of requirements for AFS generally and adaptive lighting in particular. Unlike the FMVSS, which rely on manufacturer self-certification, ECE requirements for ADB systems utilize the type approval framework used throughout the ECE standards. Under the type approval framework, production samples of new model cars must be approved by regulators before being offered for sale. This approval is based, in part, on testing whole vehicles on public roadways to verify performance. The ECE requirements specify that the adaptation of the main-beam not cause any discomfort, distraction or glare to the driver of the ADB-equipped vehicle or to oncoming and preceding vehicles. This is demonstrated through the technical service performing a test drive

[29] S9.4.1.

[30] John D. Bullough, Nicholas P. Skinner, Yukio Akashi, & John Van Derlofske. 2008. Investigation of Safety-Based Advanced Forward-Lighting Concepts to Reduce Glare, DOT HS 811 033. Washington, DC: National Highway Traffic Safety Administration, p. 63. *See also, e.g.*, Mary Lynn Mefford, Michael J. Flannagan & Scott E. Bogard. 2006. Real-World Use of High-Beam Headlamps, UMTRI–2006–11. University of Michigan, Transportation Research Institute, p. 6 (finding that "high-beam headlamp use is low . . . consistent with previous studies that used different methods").

[31] Investigation of Safety-Based Advanced Forward-Lighting Concepts to Reduce Glare, DOT HS 811 033, p. 63.

[32] Michael J. Flannagan & John M. Sullivan. 2011. Preliminary Assessment of The Potential Benefits of Adaptive Driving Beams, UMTRI–2011–37. University of Michigan, Transportation Research Institute, p. 2.

[33] 2007 Report to Congress, p. 6. A recent study by the Insurance Institute for Highway Safety noted that "[t]wenty-nine percent of all fatalities during 2014 occurred in the dark on unlit roads. Although factors such as alcohol impairment and fatigue contributed to many of these crashes, poor visibility likely also played a role." Ian J. Reagan, Matthew L. Brumbelow & Michael J. Flannagan. 2016. The Effects of Rurality, Proximity of Other Traffic, and Roadway Curvature on High Beam Headlamp Use Rates. Insurance Institute for Highway Safety, pp. 2–3 (citations omitted). *See also* Feasibility Study, p. 5 ("The conclusion of our analysis was that pedestrian crashes were by far the most prevalent type of crash that could in principle be addressed by headlighting."). See Appendix A for an analysis that roughly estimates the target population that could benefit from ADB technology.

[34] Letter from Thomas Zorn, Volkswagen Group of America to Dr. Mark Rosekind, Administrator, NHTSA, Petition for Temporary Exemption from FMVSS 108 (October 10, 2016), pp. 1, 7.

[35] *See, e.g.*, SAE J3069 ("However, in the United States it is unclear how ADB would be treated under the current Federal Motor Vehicle Safety Standard (FMVSS) 108.").

[36] Letter from Tom Stricker, Toyota Motor North America, Inc. to David Strickland (Mar. 29, 2013).

[37] Regulation 48 defines AFS as "a lighting device type-approved according to Regulation No. 123, providing beams with differing characteristics for automatic adaptation to varying conditions of use of the dipped-beam (passing-beam) and, if it applies, the main-beam (driving-beam)."

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on various types of roads (*e.g.*, urban, multi-lane roads, and country roads), at a variety of speeds, and in a variety of specified traffic conditions.[38] The performance of the ADB system is evaluated based on the subjective observations of the type approval engineer during this test drive.

IV. NHTSA Research Related to ADB

There are two components to NHTSA's ADB-related research—the 2012 Feasibility Study and the 2015 ADB Test report. This research develops objective criteria and test procedures to evaluate whether an ADB system glares oncoming or preceding vehicles.

The Feasibility Study derives vehicle-based photometric requirements to control glare from the current equipment-based photometric test points in FMVSS No. 108. As explained above, the existing lower-beam photometry requirements regulate glare by specifying the maximum intensity of light permitted at certain specified portions of the lower beam that are directed towards oncoming or preceding vehicles. These requirements are set out in Table XIX of FMVSS No. 108. Four of these test points regulate headlamp glare.[39] Two of these test points correspond to locations of oncoming vehicles (*i.e.*, to the left of the lamp and slightly above horizontal),[40] and two correspond to glare to preceding vehicles (*i.e.*, to the right of the lamp and slightly above horizontal).[41] Table XIX specifies the maximum intensity of light that may be emitted in these directions. So, for example, a lower beam may not provide more than 1,000 candela[42] (cd) at 0.5 degrees up, and 1.5 degrees to the left. These photometric requirements are for an individual headlamp (as a piece of equipment, and tested in a laboratory), not for a headlighting system as installed on a vehicle.

The Feasibility Study translates these equipment requirements into vehicle-based photometric requirements for an entire headlighting system by translating them into three-dimensional space around a vehicle (picture a cloud of points in front of the vehicle). It derives groups of test points to control glare to oncoming and preceding drivers. These test points correspond to where an oncoming or preceding vehicle would be on the road in relation to the vehicle. For each of these points there is a maximum illuminance[43] level—a level of light that should not be exceeded. The maximum allowed illuminance level depends on how far in front of the vehicle the test point is. That is, the Feasibility Study derives the maximum amount of light that should be directed toward an oncoming or preceding vehicle, based on how far the oncoming or preceding vehicle is from the ADB-equipped vehicle ("derived glare limits"). Additional details on this derivation can be found in the Feasibility Study.

NHTSA conducted testing and research to develop an objective and repeatable performance test to evaluate whether an ADB system exceeds the derived glare limits. The testing was based on the ECE R48 test drive scenarios and the derived glare limits.

We evaluated and refined a range of test track scenarios based on the ECE test drive specifications. These included a variety of types of roadway geometry (*e.g.*, curved, straight, winding), and maneuver scenarios (*e.g.*, encountering an oncoming vehicle, or passing a preceding vehicle). We ran the tests on a closed test track with three types of "stimulus" vehicles (the vehicle that was used to interact with the ADB-equipped vehicle and stimulate the adaptive driving beam): A large stimulus vehicle, a small stimulus vehicle, and a motorcycle. Scenarios varied the speed of both the ADB-equipped vehicle and the stimulus vehicle (anywhere from stationary to 67 mph).

We also developed methods and procedures to objectively assess ADB system performance on these test track drives. As noted above, ADB performance on the ECE test drive is evaluated based on the subjective observations of the type approval engineer. NHTSA's statute requires, however, that an FMVSS be objective. To objectively measure the amount of light cast on oncoming and preceding vehicles by the ADB-equipped vehicle, the stimulus vehicle was equipped with photometers[44] mounted at locations where light from the ADB headlamps could glare the driver of the stimulus vehicle—for example, on an outside rear view mirror, or in front of the windshield near the driver's eyes.[45] The ADB-equipped vehicle and one or more of the stimulus vehicles were then run through the various driving scenarios on closed courses at a vehicle testing facility. During these test runs illuminance data from the photometers was recorded as was position data for vehicles. A variety of adjustments were made to the illuminance and position data (for example, the recorded illuminance values were adjusted to account for ambient light).

To evaluate the performance of the ADB system, NHTSA used simplified versions of the derived glare limits reported in the Feasibility Study. This resulted in two sets of glare limits: One set for glare to oncoming vehicles and one set for glare to preceding vehicles. The glare limits are specified with respect to the distance between the ADB-equipped vehicle and either the oncoming or preceding stimulus vehicle (see Table 1 and Table 2). The specified glare limit is the maximum amount of light that may be cast on an oncoming or preceding vehicle within that distance interval. The recorded illuminance values were compared with the derived glare limit corresponding to the distance at which the illuminance value was recorded. If the recorded illuminance value exceeded the derived glare limit, this was considered a test failure.

TABLE 1—LIMITS FOR GLARE TO ONCOMING VEHICLES

Range from headlamp to photometer (m)	Maximum illuminance (lux)
15.0–29.9	3.1
30.0–59.9	1.8
60.0–119.9	0.6
120.0–239.9	0.3

TABLE 2—LIMITS FOR GLARE TO PRECEDING VEHICLES

Range from headlamp to photometer (m)	Maximum illuminance (lux)
15.0–29.9	18.9
30.0–59.9	18.9
60.0–119.9	4.0
120.0–239.9	4.0

[38] *See* Annex 12 to ECE R48.

[39] More specifically, they regulate glare that comes directly from the headlamps (as opposed to headlamp glare that reflects off of, say, the road surface).

[40] 1U, 1.5L to L (700 cd maximum); 0.5U, 1.5L to L (1,000 cd maximum).

[41] 1.5U, 1R to R (1,400 cd maximum); 0.5U, 1R to 3R (2,700 cd maximum).

[42] Candela is a unit of measurement of luminous intensity. Candela is a measure of the amount of light coming from a source per unit solid angle.

[43] Illuminance is the amount of light falling on a surface. The unit of measurement for illuminance is lux. Lux is a unit measurement of illuminance describing the amount of light falling on a surface, whereas candela is a measure of the luminous intensity produced by a light source in a particular direction per solid angle. A measure of luminous intensity in candela can be converted to a lux equivalent, given a specified distance.

[44] A photometer, or illuminance meter, is an instrument that measures light.

[45] The motorcycle was not fitted with photometers because of time constraints and equipment availability. Illuminance receptors were located on a vehicle positioned adjacent to the motorcycle; this vehicle's lamps remained off to ensure that the ADB-equipped vehicle was responding only to the motorcycle's lamps.

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We tested four different ADB-equipped vehicles that were approved and sold in Europe: A MY 2014 Audi A8 equipped with MatrixBeam; a MY 2014 BMW X5 xDrive35i equipped with Adaptive High-Beam Assist; a MY 2014 Lexus LS460 F Sport equipped with Adaptive High-Beam System; and a MY 2014 Mercedes-Benz E350 equipped with Adaptive Highbeam Assist. The beam patterns on the Audi and Mercedes headlamps were FMVSS No. 108-compliant. Activation speeds for these ADB systems ranged from 19 to 43 mph.[46] The Agency analyzed the research in a variety of ways, including assessments for repeatability.

In these tests, ADB appeared to provide noticeable additional roadway illumination. ADB adaptation was more apparent in some vehicles than others. However, in many cases ADB did not succeed in maintaining glare in the location of other vehicles to lower beam levels. Generally, the Agency's testing suggested that when an ADB system has a long preview of another vehicle, ADB can perform well. When an ADB system does not have a long preview of another vehicle, such as in an intersection scenario or when two vehicles are oncoming on a curved road, ADB may not adapt its beam pattern quickly enough. Additionally, some ADB system behaviors that were not expected and uncharacteristic of ADB's stated purpose were observed, such as instances of momentary engagement of the upper beam or interpreting a reflective roadside sign to be another vehicle and suddenly darkening the forward roadway. Because this research evaluated ADB systems installed on MY 2014 vehicles, current ADB systems may be capable of better performance.

The Agency's test report made a number of observations based on its analysis of the testing data. Here, the Agency notes several. First, testing confirmed the validity of the derived glare limits. For example, the illuminance of the lower beams of the ADB systems equipped with an FMVSS No. 108-compliant lower beam was within the glare limits when measured on the test track with the vehicle stationary. Second, the research demonstrated that achieving a valid whole-vehicle test procedure for assessing ADB headlighting system performance with respect to relevant performance criteria is technically feasible. The results showed that making such measurements outdoors in variable ambient illumination conditions can be performed in a valid way, by removing the measured ambient illumination from the recorded headlighting system test trial data. For example, ADB response timing seemed consistent across trials. Scenarios involving the stimulus vehicle and ADB-equipped vehicle driving toward each other showed ADB adaptation occurring at closer range between vehicles than would be seen if the stimulus vehicle is stationary because of the ADB response timing. Third, the testing showed that this whole-vehicle test procedure could be accomplished in a repeatable manner. Specific testing results are discussed in more detail in the docketed test report and data and in subsequent sections of this preamble. Repeatability is discussed in more detail in Section VIII.c.

[46] ADB Test Report, p. 20.

V. SAE J3069

In 2016, SAE published a standard for adaptive driving beam systems, SAE J3069 JUN 2016, Adaptive Driving Beam. The standard specifies a road test to determine whether an ADB system glares oncoming or preceding vehicles. The standard specifies, as performance criteria, glare limits based on and similar but not identical to the glare limits used in the ADB Test Report (See Table 3).

SAE J3069 specifies a straight test track with a single lane 155 m long. On either side of this test lane, the standard specifies the placement of test fixtures simulating an opposing or preceding vehicle. The test fixtures are fitted with lamps having a specified brightness, color, and size similar to the taillamps and headlamps on a typical car, truck, or motorcycle. The standard specifies four test fixtures: An opposing car/truck; an opposing motorcycle; a preceding car/truck; and a preceding motorcycle. In addition to simulated vehicle lighting, the test fixtures are fitted with photometers to measure the illumination from the ADB headlamps.

The standard specifies a total of eighteen different test drive scenarios. The scenarios vary the test fixture used, the placement of the fixture (*i.e.*, to the right or left of the lane in which the ADB-equipped vehicle is travelling), and whether the lamps on the test fixture are illuminated for the entire test drive, or are instead suddenly illuminated when the ADB vehicle is close to the test fixture. During each of these test runs, the illuminance recorded at 30 m, 60 m, 120 m, and 155 m must not exceed the specified glare limits. If there is no recorded illuminance value at any of these distances, interpolation is used to estimate the illuminance at that distance. For sudden appearance tests, the system is given a maximum of 2.5 seconds to react and adjust the beam. If any recorded (or interpolated) illuminance value exceeds the applicable glare limit, the standard provides for an allowance: The same test drive scenario is run, except now only the lower beam is activated. The ADB system can still be deemed to have passed the test as long as any of the ADB exceedances do not exceed 125% of the measured (or interpolated) illuminance value(s) for the lower beam.

TABLE 3—SAE J3069 GLARE LIMITS

Range from headlamp to photometer (m)	Maximum illuminance, oncoming (lux)	Maximum illuminance, preceding (lux)
30	1.8	18.9
60	0.7	8.9
120	0.3	4.0
155	0.3	4.0

In addition to the dynamic track test, the standard contains a number of other system requirements, such as physical test requirements and requirements for the telltale. It also requires the system to comply with certain aspects of existing standards for lower and upper beam photometry as measured statically in a laboratory environment (for example, for the portion of the ADB beam that is directed at areas of the roadway unoccupied by other vehicles, the lower beam minimum values specified in the relevant SAE standard must be met).

In the Proposal and Regulatory Alternatives sections of this document we discuss specific provisions of SAE J3069 in more detail.

VI. Interpretation of How FMVSS No. 108 Applies to ADB

NHTSA has never squarely addressed whether ADB technology is permitted under existing FMSS No. 108 requirements. Here we address this issue and consider requirements in FMVSS No. 108 that could pose regulatory obstacles to the introduction of ADB in the United States. We first consider whether ADB technology would be permissible under FMVSS No. 108 as supplemental lighting and conclude it is not supplemental lighting. We then consider whether an ADB system would comply with the current FMVSS No. 108 requirements for headlights. As we explain below, ADB would likely not comply with at least some of these requirements, particularly the photometry and semiautomatic beam switching device requirements. We tentatively conclude that FMVSS No. 108 currently would not permit the installation of ADB on motor vehicles.

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a. ADB Is Not Supplemental Lighting But Is Part of the Required Headlamp System

The threshold issue is whether an ADB system is supplemental or required lighting. FMVSS No. 108 specifies, for each class of vehicle, certain required and optional (if-equipped) lighting elements. The standard sets out various performance requirements for the required and optional lighting elements. The standard also allows vehicles to be equipped with lighting not otherwise regulated as required or optional equipment. This type of lighting equipment is referred to as supplemental or auxiliary lighting. Supplemental lighting is permitted if it does not impair the effectiveness of lighting equipment required by the standard.[47] There are two different but related reasons leading us to tentatively conclude that an ADB system is not supplemental lighting.

First, ADB systems are not supplemental lighting because they fit the definition of "semiautomatic beam switching device," a headlighting device that is specifically regulated by the standard. FMVSS No. 108 requires that vehicles be equipped with a headlamp switching device that provides "a means of switching between lower and upper beams designed and located so that it may be operated conveniently by a simple movement of the driver's hand or foot."[48] As an alternative to this requirement, the standard allows a vehicle to be equipped with a semiautomatic means of switching between the lower and upper beams.[49] The standard defines "semiautomatic headlamp beam switching device" as "one which provides either automatic or manual control of beam switching at the option of the driver. When the control is automatic the headlamps switch from the upper beam to the lower beam when illuminated by the headlamps on an approaching vehicle and switch back to the upper beam when the road ahead is dark. When the control is manual, the driver may obtain either beam manually regardless of the conditions ahead of the vehicle."[50]

We have tentatively concluded that an ADB system is a semiautomatic beam switching device under FMVSS No. 108 because an ADB system automatically switches between an upper beam and a lower beam. An upper beam is defined in the standard as "a beam intended primarily for distance illumination and for use when not meeting or closely following other vehicles."[51] A lower beam is defined as "a beam intended to illuminate the road and its environs ahead of the vehicle when meeting or closely following another vehicle."[52] The beam an ADB system emits when there are no preceding or oncoming vehicles is the upper beam; the beam it emits when there are preceding or oncoming vehicles is a lower beam.[53] ADB technology differs from standard headlighting technology in that it can provide a variety of lower beam patterns tailored to fit the particular traffic situation it is confronted with. For ease of reference, we will refer to the "base" lower beam as the lower beam pattern produced by the ADB system that is the same as the lower beam the headlighting system would produce if it were not ADB-equipped, and the "augmented" lower beam as the enhanced lower beam with which the system illuminates the roadway when at least some portion(s) of the forward roadway is unoccupied by other vehicles. If the forward roadway is sufficiently occupied by other vehicles (either oncoming or preceding) so there is no portion of the roadway that could be illuminated with additional light without glaring other vehicles, the ADB system produces a base lower beam; if the forward roadway is at least partially unoccupied, the system produces an augmented lower beam, in which at least some portions of the beam pattern are brighter than the corresponding portions in the pattern of the base lower beam. An ADB system can provide a variety of different augmented lower beam patterns, depending on the traffic situation. However, each of these augmented beams is, by definition, a lower beam. Because an ADB system provides either automatic or manual control of beam switching at the option of the driver, and, when the control is automatic the headlamps switch between an upper beam and a lower beam, it is a semiautomatic headlamp beam switching device. The standard has specific requirements for semiautomatic beam switching devices (we discuss these requirements in more detail below and in the Proposal section of this document). Because ADB is regulated by these requirements, it is not supplemental lighting.

Second, ADB is not supplemental lighting under NHTSA's interpretation of the term "supplemental lighting." FMVSS No. 108 requires vehicles to be equipped with one of several permissible headlighting systems, whose specifications are set forth in the standard. Headlighting systems are comprised of headlamps and associated hardware. The purpose of headlighting is primarily to provide forward illumination.[54] In determining whether lighting equipment providing forward illumination is supplemental or required, NHTSA looks at several factors: (1) Where the lamp directs its light; (2) whether it uses a headlamp replaceable light source to emit a beam that provides significantly more light flux than supplemental cornering lamps or fog lamps designed to conform to applicable SAE standards; (3) whether the lamp is intended to be used regularly or is limited (as are fog lamps) to more narrow driving conditions and situations; and (4) whether there is a manual on/off switch.[55] For example, in a 2004 interpretation letter, NHTSA used these factors to evaluate a swiveling lamp included as part of a vehicle front lighting system meeting the FMVSS No. 108 requirements without the lamp. The lamp was designed to automatically enhance forward illumination around corners and through curves to improve a driver's ability to see pedestrians, bicycles, and other objects. NHTSA concluded the lamp was part of the required headlighting system, and thus not supplemental lighting, and therefore subject to the headlamp requirements.[56]

Under this analysis, we tentatively conclude an ADB system is part of the required headlighting system and not supplemental lighting. Most importantly, an ADB system, in contrast to supplemental lamps such as cornering lights or fog lamps, provides significantly more light flux forward of the vehicle and is intended to be used regularly.[57] ADB systems function, and

[47] S6.2.1.

[48] S9.4.

[49] S9.4.1.

[50] S4.

[51] *Id.*

[52] *Id.*

[53] This is consistent with SAE J3069 JUN2016, which considers ADB as "an addition to or equivalent to the lower beam."

[54] S4 "*Headlamp* means a lighting device providing an upper and/or a lower beam used for providing illumination forward of the vehicle." (formatting in original).

[55] Letter from Jacqueline Glassman, Chief Counsel, to [Redacted] (Jan. 21, 2004) (opining that a "swiveling lamp" is a component of the required headlighting system). *See also* Letter from John Womack, Acting Chief Counsel, to M. Guy Dorleans, Valeo Vision (Aug. 31, 1994) (treating an auxiliary driving beam as part of the required headlighting system); Letter from Frank Berndt, Chief Counsel, to I.A. Wuddel, Hueck & Co. (Nov. 18, 1983) (treating an auxiliary driving beam as part of the required headlighting system and alternatively treating it as a supplemental light). All interpretations cited in this document are available at *https://isearch.nhtsa.gov/*.

[56] Letter from Jacqueline Glassman, Chief Counsel, to [Redacted] (Jan. 21, 2004).

[57] *See* Letter from Frank Berndt, Chief Counsel, to Robert Bosch Corp. (Feb. 11, 1977) (finding that fog

Continued

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are intended to function, as the primary source of forward illumination for the vehicle when they are activated. This is a safety-critical function affecting not only the ADB-equipped vehicle but also (through glare) other vehicles. The purpose of the headlighting requirements is to ensure headlighting systems attend to both these safety-critical issues and strike an acceptable balance between forward visibility and glare. The entire purpose of ADB technology is to strike this balance more robustly and effectively. It therefore seems appropriate that ADB is considered an element of required lighting and not merely supplemental lighting.

We note that prior to the 2004 interpretation letter, NHTSA had issued several interpretations concerning auxiliary driving beams in which the Agency treated, without directly considering the issue, those lamps as supplemental lighting.[58] If the lamps in question in those earlier interpretations would be considered supplemental lighting under the factors set forth in the 2004 interpretation, they may be consistent with that later interpretation. There is not, however, sufficient information about the lighting systems at issue in those earlier interpretations letters to be able to apply the factors from the 2004 interpretation. In any case, the 2004 interpretation has been, to date, NHTSA's view on the issue. Because of the reasons given above, we tentatively conclude that changing that interpretation is not warranted at this time.

b. ADB Systems Would Not Comply With at Least Some of the Headlamp Requirements

Because we tentatively conclude that an ADB system is part of the required headlamp system, we next consider whether there are any headlamp requirements with which it would not comply. We tentatively conclude that an ADB system would likely not comply with certain of the requirements for lower beam photometry and semiautomatic beam switching devices.

i. Photometry Requirements

An ADB system would have to comply with all applicable photometry requirements. As discussed earlier, there are separate photometry requirements for lower and upper beams. The photometry requirements specify test points, with each test point specifying minimum levels of light (to ensure adequate illumination) and/or maximum levels of light (to limit glare to oncoming or preceding vehicles). When an ADB system is emitting an upper beam, the upper beam must conform to the upper beam photometry requirements, and when it is emitting a lower beam it must conform to the lower beam photometry requirements.[59]

The upper beam of an ADB system would likely be able to comply with the upper beam photometry requirements. This is because the ADB upper beam would, or should, be the same as the upper beam on the non-ADB-equipped version of that vehicle. Accordingly, an ADB system's upper beam presumably would comply with the upper beam photometric requirements.

The ADB system's lower beam, on the other hand, would probably not always comply with the lower beam photometric requirements. An ADB system can produce a variety of lower beams; each lower beam must comply with the applicable lower beam photometric requirements. The base lower beam is designed to conform to the current lower beam photometry requirements. However, the augmented lower beam(s) provide more illumination than the base lower beam would; the purpose of ADB is to produce a lower beam providing more illumination than a current FMVSS No. 108-compliant lower beam. Therefore, it is likely that the augmented lower beam would not always comply with existing lower beam photometry requirements. Toyota appears to allude to this in its petition when it states that "[w]hile the variable beam pattern mode does occasionally emit asymmetric candlepower that is above the maxima or below the minima at certain FMVSS No. 108 test points, these differences are always designed to be consistent with satisfying the dual goals of minimizing glare to oncoming and preceding drivers and enhancing the forward and sideways illumination for the benefit of the driver in the AHS-equipped vehicle." [60] Volkswagen, in a recent exemption petition, also notes that "the Audi Matrix Beam ADB system does not conform to FMVSS 108 photometric requirements at certain test points." [61]

We also note that in the 2003 Request for Comments regarding advanced headlighting systems mentioned earlier, the Agency considered, among other things, advanced headlighting systems that could actively re-aim the lower beam horizontally (so-called "bending light"). NHTSA concluded that FMVSS No. 108 does not prohibit bending light headlamps because the standard does not specifically address initial or subsequent headlamp aim (the standard addresses only aimability requirements). Advanced headlighting systems that can actively re-aim the lower beam horizontally are currently available as original and replacement equipment in the U.S.

ii. Semiautomatic Beam Switching Device Requirements

We have tentatively concluded that an ADB system is a semiautomatic beam switching device under FMVSS No. 108. ADB systems could likely meet some, but not all, requirements applicable to these devices.

FMVSS No. 108 sets forth a variety of performance requirements for semiautomatic beam switching devices. ADB systems would likely be able to meet some of the existing semiautomatic beam switching device requirements: Owner's manual operating instructions (S9.4.1.1); manual override (S9.4.1.2); fail safe operation (S9.4.1.3); and automatic dimming indicator (S9.4.1.4). We propose applying these requirements to ADB systems. However, ADB systems likely would not comply with other requirements applicable to semiautomatic beam switching devices. One of the requirements is that semiautomatic headlamp beam switching devices must provide lower and upper beams complying with relevant photometry requirements. As we explain in the section immediately above, an ADB system would not comply with the lower beam

lamp is supplemental lighting); Letter from Erika Z. Jones, Chief Counsel, to M. Iwase, Koito Mfg. Co., Ltd. (March 31, 1986) (same); Letter from Erika Z. Jones, Chief Counsel, to T. Chikada, Stanley Elec. Co. (June 19, 1987) (same); Letter from Erika Z. Jones, Chief Counsel to Byung M. Soh, Target Marketing Sys., Inc. (Sept. 13, 1988) (same); Letter from Erika Z. Jones, Chief Counsel, to Sadato Kadoya, Mazda (North America), Inc. (Nov. 3, 1988) (same); Letter from Philip Recht, Chief Counsel, to Melinda Dresser, Carlin Mfg. (January 9, 1985) (same); Letter from John Womack, Acting Chief Counsel, to Yohsiaki Matsui, Stanley Elec. Co. (Sept. 20, 1995) (same).

[58] *See* Letter from Erika Z. Jones, Chief Counsel, to P. Soardo, Instituto Elettrotecnico Nazionale (May 22, 1987); Letter from S.P. Wood to Subaru of America, Inc. (Oct. 31, 1978); Letter from Erika Z. Jones, Chief Counsel, to Byung M. Soh, Target Marketing Sys., Inc. (Sept. 13, 1988); Letter from Erika Z. Jones, Chief Counsel to George Ziolo (Sept. 12, 1988); Letter from Frank Berndt, Chief Counsel, to I.A. Wuddel, Hueck & Co. (Nov. 18, 1983).

[59] We note it does not appear possible to interpret the standard so the dimmed portion of the ADB beam is subject to the lower beam photometry requirements and the undimmed portion is subject to upper beam photometry requirements because S9.4.1 prohibits simultaneous activation of upper and lower beams (except for signaling or switching, neither of which is applicable here).

[60] Letter from Tom Stricker, Toyota Motor North America, Inc. to David Strickland (Mar. 29, 2013), p. 3.

[61] Letter from Thomas Zorn, Volkswagen Group of America to Dr. Mark Rosekind, Administrator, NHTSA, Petition for Temporary Exemption from FMVSS 108 (October 10, 2016), p. 2.

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photometry requirements in all instances. Other requirements include fail safe operation requirements, mounting height limitations, and a series of physical tests, including a sensitivity test. Some of these would be difficult to apply to, or would not sensibly apply to, an ADB system.

c. Tentative Determination

We tentatively conclude that ADB would not be supplemental lighting and would likely not comply with at least some of the lower beam photometric and semiautomatic beam switching device requirements. We therefore tentatively conclude that FMVSS No. 108 would, in its current form, preclude an ADB system as original or replacement equipment.

Although we tentatively conclude that an ADB system is part of the required headlighting system, we briefly consider the status of ADB technology if it were instead considered supplemental equipment. If we were to instead determine that an ADB system is supplemental lighting, it would be permissible provided it did not impair the effectiveness of any of the required lighting (S6.2.1). A vehicle manufacturer must certify that supplemental lighting installed as original equipment complies with S6.2.1 (although, as a practical matter, vehicle manufacturers generally insist that equipment manufacturers provide assurance that their products meet Federal standards). Effectiveness may be impaired if, among other things, supplemental lighting creates a noncompliance in the existing lighting equipment or confusion with the signal sent by another lamp, or functionally interferes with it, or modifies its candlepower to either below the minima or above the maxima permitted by the standard.[62] The judgment of impairment is one made by the person installing the device, although that decision may be questioned by NHTSA if it appears erroneous.

If an ADB system were installed as supplemental equipment, it would impair the effectiveness of the required headlighting system if it did not meet the Table XVIII (upper beam) test points corresponding to unoccupied portions of the road, or if it did not meet the Table XIX (lower beam) test points corresponding to portions of the road on which an oncoming or preceding vehicle was located.[63] It would, however, be difficult for NHTSA to verify this because the Table XVIII and XIX photometric test points are premised on laboratory measurements, whereas whether an ADB system is functioning properly depends on whether it is accurately detecting oncoming and preceding vehicles in actual operation on the road. Accordingly, even if NHTSA were to adopt this alternative interpretation, it still might not obviate the need for this rulemaking.

We seek comment on this tentative interpretation. In addition, we seek comment on whether there are provisions in FMVSS No. 108 we have not identified in this document that might apply to ADB systems and so should be amended.

VII. NHTSA's Statutory Authority

NHTSA is proposing this NPRM pursuant to its authority under the Motor Vehicle Safety Act. Under 49 U.S.C. chapter 301, Motor Vehicle Safety (49 U.S.C. 30101 *et seq.*), the Secretary of Transportation is responsible for prescribing motor vehicle safety standards that are practicable, meet the need for motor vehicle safety, and are stated in objective terms.[64] "Motor vehicle safety" is defined in the Motor Vehicle Safety Act as "the performance of a motor vehicle or motor vehicle equipment in a way that protects the public against unreasonable risk of accidents occurring because of the design, construction, or performance of a motor vehicle, and against unreasonable risk of death or injury in an accident, and includes nonoperational safety of a motor vehicle."[65] "Motor vehicle safety standard" means a minimum performance standard for motor vehicles or motor vehicle equipment.[66] When prescribing such standards, the Secretary must consider all relevant, available motor vehicle safety information.[67] The Secretary must also consider whether a proposed standard is reasonable, practicable, and appropriate for the types of motor vehicles or motor vehicle equipment for which it is prescribed and the extent to which the standard will further the statutory purpose of reducing traffic accidents and associated deaths.[68] The responsibility for promulgation of Federal motor vehicle safety standards is delegated to NHTSA.[69] The Agency carefully considered these statutory requirements in developing this proposal. We evaluate the proposal with respect to these requirements in subsequent sections of this preamble.

VIII. Proposed Requirements and Test Procedures

We propose amending NHTSA's lighting standard to allow ADB systems on vehicles in the United States and ensure that they operate safety with respect to the twin safety needs of glare prevention and visibility.

We have tentatively concluded that because ADB has the potential to provide significant safety benefits, FMVSS No. 108 should be amended in order to permit it. ADB technology has the potential to reduce the risk of crashes by increasing visibility without increasing glare. In particular, it offers potentially significant safety benefits in preventing collisions with pedestrians, cyclists, animals, and roadside objects. We have tentatively concluded, however, that ADB would not comply with FMVSS No. 108 because an ADB system is part of the required headlighting system—not supplemental lighting—and would likely not comply with at least some existing lighting requirements. Accordingly, we propose amending FMVSS No. 108 to permit ADB systems on vehicles in the U.S.

We have also tentatively concluded that in order to ensure that ADB systems operate safely, the standard should be amended to include additional requirements specific to ADB systems. Because ADB uses relatively new, advanced technology to provide an enhanced lower beam and dynamically changes the beam to accommodate the presence of other vehicles, it has the potential—if it does not function properly—to glare other motorists. NHTSA is particularly sensitive to concerns about glare in light of the history of glare complaints from the public, the 2005 Congressional mandate, and the Agency's research. Because the existing headlighting regulations (in particular, the photometry requirements) are based on and intended for the current, static beams, they do not have any requirements or

[62] *See, e.g.*, Letter from Erika Jones, Chief Counsel, to Byung M. Soh, Target Marketing Systems, Inc. (Sept. 13, 1988).

[63] *See* Feasibility Study, p. 36 (Fig. 19) (locations of upper beam test points) and p. 16 (Fig. 5) (locations of lower beam test points). *See also* Letter from Erika Z. Jones, Chief Counsel to George Ziolo (Sept. 12, 1988) (finding that a supplemental headlamp would impair the effectiveness of the headlighting system because it caused the upper beam to exceed the upper beam photometric maxima); Letter from Erika Z. Jones, Chief Counsel, to Byung M. Soh, Target Marketing Sys., Inc. (Sept. 13, 1988) (finding that a supplemental headlamp intensity modulator would impair the effectiveness of the headlighting system because it would not necessarily comply with upper or lower beam photometric requirements).

[64] 49 U.S.C. 30111(a).

[65] 49 U.S.C. 30102(a)(8).

[66] 30102(a)(9).

[67] 30111(b)(1).

[68] 30111(b)(3)–(4).

[69] *See* 49 CFR 1.95.

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test procedures to evaluate whether an ADB system is functioning properly as it dynamically changes the beam to accommodate other vehicles. We therefore propose amending FMVSS No. 108 to include requirements and test procedures specifically tailored to ensure that ADB systems do not glare other motorists. NHTSA is also proposing a limited set of requirements to ensure that ADB systems provide adequate visibility at all times.

First, we propose amending FMVSS No. 108 to allow ADB systems. We propose amendments to, among other things, the lower beam photometry requirements so that the enhanced lower beam provided by ADB technology is permitted.

Second, we propose requirements to ensure that ADB systems do not glare other motorists. ADB systems provide an enhanced lower beam that provides more illumination than the currently-allowed lower beam. If ADB systems do not function properly—detect oncoming and preceding vehicles and shade them accordingly—other motorists will be glared. The proposal addresses this safety concern with a combination of vehicle-level track tests and equipment-level laboratory testing requirements.

The centerpiece of the proposal is a vehicle-level track test to evaluate ADB performance in recognizing and not glaring other vehicles. We propose evaluating ADB performance in a variety of different types of interactions with oncoming and preceding vehicles (referred to as "stimulus" vehicles because they stimulate a response from the ADB system). The stimulus vehicle would be equipped with sensors to measure the illuminance from the ADB system near the driver's eyes (or rearview mirrors). We propose a variety of different test scenarios. The scenarios vary the road geometry (whether it is straight or curved); vehicle speeds (from 0 to 70 mph); and vehicle orientation (whether the stimulus vehicle is oncoming or preceding). The illumination cast on the stimulus vehicle would be measured and recorded throughout the test run. In order to evaluate ADB performance in these test runs, we are proposing a set of glare limits. These are numeric illuminance values that would be the maximum allowable illuminance the ADB system would be permitted to cast on the stimulus vehicle. The proposed glare limits and test procedures are based on NHTSA's ADB-related research and are intended to ensure that an ADB system is capable of correctly detecting oncoming and preceding vehicles and not glaring them. They differ from the existing photometry requirements because they are vehicle-level requirements tested on a track.

In addition to this track test, we also propose a small set of equipment-level laboratory testing requirements related to glare prevention. We propose to require that the dimmed portion of the adaptive beam (*i.e.*, the light directed towards an oncoming or preceding vehicle) not exceed the current low beam maxima, and that in the undimmed portion of the adaptive beam (*i.e.*, the light directed towards unoccupied roadway) the current upper beam maxima not be exceeded. These tests would be carried out at the component level—on the headlamps (not installed on the vehicle) in a photometric laboratory. These proposed requirements would essentially subject the ADB system to laboratory tests of the beam similar to what are currently required for standard headlights. NHTSA anticipates that manufacturers would be able to certify to these photometry requirements in a typical photometric laboratory using typical test procedures, with the addition of a headlamp beam controller simulating the signal sent to headlamps from the camera/headlamp controller.

Third, we propose a limited set of minimum illumination requirements (as tested in a laboratory) to ensure that the ADB system provides sufficient visibility for the driver. The current headlamp requirements include, in addition to maximum light levels in certain directions, minimum levels of illumination to ensure that the driver has a minimum level of visibility. We propose that these existing laboratory photometry tests be applied to the ADB system to ensure that the ADB beam pattern, although dynamically changing, always provides at least a minimum amount of light. We propose requiring that the dimmed portion of the adaptive beam meet the current lower beam minima and that that in the undimmed portion of the adaptive beam the current upper beam minima be met. These minimum levels of illuminance are in a direction such that they would not glare other motorists. Again, NHTSA anticipates that manufacturers will be able to certify to these photometry requirement in a typical photometric laboratory.

Finally, we propose several other system requirements to ensure that an ADB system operates safely. Some of these requirements, such as manual override, are already part of the existing regulations for semiautomatic beam switching devices, and are being extended to ADB systems. Other requirements such as one that the system notify the driver of a fault or malfunction, would be specific to ADB systems.

a. Requirements

This NPRM proposes to subject ADB-equipped vehicles to a dynamic compliance test to ensure the ADB system does not glare oncoming or preceding vehicles. The performance requirements we propose specify the maximum level of illuminance an ADB system may cast on opposing or preceding vehicles. In addition to these glare limit requirements, we are proposing a set of minimum system requirements to ensure an ADB system performs safely.

i. Baseline Glare Limits

The foundation of this rulemaking is a set of glare limits specifying the amount of light that may be directed towards oncoming or preceding vehicles. The glare limits we propose are the same limits used in the ADB Test Report and presented earlier in this document in Table 1 (oncoming glare limits) and Table 2 (preceding glare limits), except instead of regulating glare out to 239.9 m, we propose to regulate glare out to 220 m. Earlier we explained how these limits were derived. These glare limits would be used to evaluate ADB headlamp illuminance as measured in a dynamic track test. (We explain the proposed test procedures later in this document.) The current photometric test points from which the proposed limits are derived are maxima; therefore, we propose applying the derived glare limits as maxima, so that any measured exceedance of an applicable glare limit would be used to determine compliance (except for momentary spikes above the limits lasting no longer than 0.1 sec. or over a distance range of no longer that 1 m). We are stating the glare limits to a precision of one decimal place, as recommended in the report that developed these glare limits.[70] For purposes of determining compliance with the glare limits, the Agency will, when conducting compliance testing, round measured illuminance values to the nearest 0.1 lux, in accordance with the rounding method of ASTM Practice E29 Using Significant Digits in Test Data to Determine Conformance with Specifications.

SAE J3069 uses glare limits drawing on and similar but not identical to the proposed glare limits. The proposed glare limits deviate from SAE J3069 in two main respects.

First, two of the glare limits differ slightly. At 60 m, SAE J3069 uses glare

[70] Feasibility Study, p. 80.

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limits of 0.7 lux (oncoming) and 8.9 lux (preceding) compared to the proposed 0.6 lux and 4.0 lux. The proposed limits are based on the 0.643 lux and 4.041 lux limits derived in the Feasibility Study, rounded to two decimal places.

Second, SAE J3069 applies to a narrower range of distances (30 m–155 m) than the proposed glare limits (15 m–220 m). Our tentative decision to regulate glare down to 15 m differs from SAE J3069, which does not apply to distances less than 30 m. At 15 m, the angle between the oncoming or preceding driver's eyes and the headlamps is small enough to cause the observer to be unable to see objects in the roadway. The 15 m cutoff we propose is consistent with the Feasibility Study and ADB Test Report, which also use glare limits for inter-vehicle distances as small as 15 m.[71] We believe it is reasonable not to regulate glare for distances smaller than 15 m because as the distance between the ADB and the oncoming vehicle decreases, the angle between the two vehicles increases; the effects of glare fall off rapidly as the angle between the glare source and the center of the observer's field of view increase. For preceding vehicles in a passing situation, we tentatively believe this is justified because at this distance the location of the driver's eye likely corresponds to a portion of the beam pattern where less light is typically projected. In addition, at smaller distances it might be difficult to obtain accurate photometry readings.

The proposal to measure and regulate glare out to 220 m is farther than either SAE J3069 (which applies only out to 155 m) or the Feasibility Study (which derived glare limits only out to 120 m) and is slightly less than in the ADB Test Report.[72] We tentatively believe it is necessary to regulate glare further than 120 m or 155 m because the upper beams can glare other roadway users at and beyond those distances. The maximum intensity allowed for each upper beam headlamp is 75,000 cd;[73] this is equivalent to 150,000 cd for a headlighting system. At 120 m, 150,000 cd is equivalent to 10.4 lux; at 155 m, this translates to 6.2 lux. Both values are greater than the 0.3 lux glare limit the Feasibility Study derived for the furthest distance it considered (120 m).

The issue then is to what maximum distance glare should be regulated. We considered regulating glare out to the distance at which the upper beams would be extremely unlikely to glare other motorists, but this would involve measuring glare at very large distances, which would not be practicable for testing purposes.[74] The maximum distance we are proposing (220 m) seems to be roughly consistent with assumptions about allowable glare implicit in state laws governing upper beam use.[75] Requiring an ADB system not exceed 0.3 lux out to 220 m would therefore preclude an ADB system from using the full upper beam once an oncoming vehicle is less than 220 m away.[76]

We believe it is practicable for OEMs to design systems complying with glare limits out to 220 m. We are simply applying the lux limit, 0.3, which was derived for 120 m, out farther, to 220 m. A headlight system able to comply with an illuminance limit of 0.3 lux at 155 m (as required by SAE J3069) should be able to comply with the same 0.3 lux limit at 220 m (because the illuminance decreases as the distance from the light source increases), as long as the ADB system is able to detect oncoming vehicles at that distance. We believe it is reasonable to expect this sort of detection capability from ADB systems; for example, the ECE ADB regulations require ADB cameras to be capable of sensing vehicles out to 400 m.[77]

We have tentatively concluded that the proposed glare limits are appropriate for use in this rulemaking. The proposed glare limits provide objective, numeric criteria to evaluate ADB system performance with respect to glare. They are based on the existing glare limits, which have been part of FMVSS No. 108 since its inception in 1967 (although the current lower beam maxima are slightly higher than the maxima incorporated by reference in the initial FMVSS). SAE has adopted glare limits similar to the proposed limits in SAE J3069. We seek comment on the appropriateness and use of the proposed glare limits. In particular, we request comment on any potential safety difference between adopting the SAE glare limits and the proposed glare limits. In addition, we seek comment on the proposal to consider any exceedance of an applicable glare limit (other than momentary spikes) to be a noncompliance. This does not take into account glare dosage, exposure, or perceptibility. Some studies suggest at least some adverse effects of glare depend on temporal duration. For example, some studies have shown that the time it takes for a driver's visual performance to return to its original state after exposure to glare (referred to as glare recovery) is proportional to the total glare or glare dosage.[78] It may also be possible that light intensities exceeding the glare limits may not be perceptible to an oncoming or preceding driver if the exposure duration is sufficiently small. Should there be a durational element to the glare limits, and if so, what should the duration be? What is the safety-related basis for the duration (*e.g.*, evidence that light intensity at or above a baseline glare limit does not have adverse effects on an oncoming or preceding motorist if the glare lasts for no longer than that duration)? Would the "any exceedance" rule potentially mean that an ADB system utilizing pulse width modulated

[71] Feasibility Study, pp. 23–24.

[72] The SAE range of 155 m appears to roughly track state laws regulating upper beam use. Many states allow drivers to use upper beams up to about 152 m (500 ft.) from an oncoming vehicle; inside of 152 m, the driver must use the lower beams. The distance requirements are smaller for preceding vehicles. *See, e.g.*, Va. Code Ann. sec. 46.2–1034 (2017); Cal. Veh. Code sec. 24409 (2017); 7 Tex. Transp. Code Ann. sec. 547.333.

[73] Table XVIII.

[74] The Feasibility Study derived a glare limit of .3 lux at 120 m for oncoming vehicles. For simplicity, and since we do not have derived glare limits for distances greater than 120 m, we apply .3 lux as the glare limit for distances greater than 120 m. (From the standpoint of regulatory stringency this is conservative, because, as the Feasibility Study explains, the allowable illuminance actually decreases as distance increases.) The maximum permissible intensity for an upper beam system is 150,000 cd, and the distance at which this will not glare an oncoming motorist is, approximately, the distance at which this will result in illuminance of .3 lux, which is 700 m. This long of a distance—almost a half mile—is not practicable for testing purposes.

[75] Many states prohibit upper beam use unless oncoming vehicles are more than approximately 155 m away. These state upper beam laws are likely based on older upper beam headlamps that were not as intense as modern headlamps. *See, e.g.*, Cal. Veh. Code sec. 24409 (2017) (requirement that driver use lower beam within 500 ft (152 m) of an oncoming vehicle enacted prior to 1978). Prior to 1978, the maximum allowable upper beam intensity for a headlighting system was 75,000 cd. *See* 61 FR 54981. At 155 m, this is equivalent to 3.1 lux. Thus, under these state laws the illumination to which an oncoming driver would be exposed would not exceed (roughly) 3.1 lux. The current photometry requirements permit a maximum upper beam intensity (for a system) of 150,000 cd. This is equivalent to 3.1 lux at 220 m. Thus, the proposal to regulate glare out to 220 m is consistent with the distance specified by state headlamp beam use laws based on the lower-intensity pre-1978 upper beam, adjusted to account for the higher-intensity upper beam allowed since 1978. That is, the distance we propose exceeds the 155 m found in many state beam use laws because headlamps are now allowed to be brighter than they were previously allowed to be.

[76] Assuming the system's upper beam is designed to produce up the maximum allowable intensity. If the upper beam were designed to produce less than the maximum allowable intensity, then the system potentially could use the full upper beam within 220 m.

[77] ECE R48 6.1.9.3.1.2.

[78] Yukio Akashi, John Van Derlofske, Jennifer Watkinson & Charles Fay. 2005. Assessment of Headlamp Glare and Potential Countermeasures: Survey of Advanced Front Lighting System (AFS). DOT HS 809 973. Washington, DC: National Highway Traffic Safety Administration, pg. 71.

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light sources could be noncompliant even though oncoming drivers would not experience glare? If so, how should this be accounted for?

ii. Existing Photometry Requirements That Would Also Apply to ADB Systems

The proposed baseline glare limits are essentially new lower beam photometric requirements with which an ADB system would have to comply when tested under the track-test procedures discussed later in this preamble. In addition to these track-tested glare limits, under this proposal an ADB system would also be subject to some of the existing laboratory-based upper and lower beam photometry requirements. When the ADB system is producing an upper beam (*i.e.* when there are no oncoming or preceding vehicles within 15 m to 220 m) we propose the beam be subject to all of the applicable Table XVIII upper beam requirements. In addition, we propose that in the undimmed portion of the adaptive beam the applicable Table XVIII upper beam maxima and minima be met. Similarly, we propose requiring that the lower beam maxima and minima be complied with within the dimmed portion of the adaptive beam.

This differs from SAE J3069 in some respects. SAE J3069 has somewhat similar provisions relating to lower and upper beam photometry, but those provisions reference the relevant SAE photometric standards; the proposal instead appropriately references the upper and lower beam photometric requirements in Tables XVIII and XIX of FMVSS No. 108. In addition, SAE J3069 only specifies that the lower beam maxima not be exceeded within the dimmed portion of the augmented lower beam, and the lower beam minima be complied with outside the dimmed portion of the augmented lower beam. We do not see any reason an ADB system's upper beam should not be subject to the same requirements as is a standard upper beam, or the dimmed and undimmed portions of the ADB adaptive lower beam should not be subjected to the applicable upper and lower beam maxima and minima. This limited set of laboratory-tested photometric requirements are an extension of the longstanding laboratory-based photometry requirements for standard headlights. The Agency requests comment on this preliminary determination. In particular, can commenters provide information on the safety impact of adopting the proposed standard versus the SAE approach?

If the Agency were to test an ADB system for compliance with these proposed requirements, the testing would be conducted as photometry testing is now tested, *i.e.,* in a laboratory using a goniometer. The Agency anticipates manufacturers will be able to certify to this photometry requirement in a typical photometric laboratory using typical test procedures, with the addition of a headlamp beam controller simulating the signal sent to headlamps from the camera/headlamp controller. For the Agency to conduct such testing, it would need to collect considerable information from the manufacturer as to how to control the headlamps to simulate the dynamic environment. NHTSA anticipates that it would consider the manufacturer's certification valid unless it is clearly erroneous or if the track testing indicates the basic headlamp photometry may be noncompliant with this requirement.

iii. Other System Requirements

We are also proposing several other requirements for ADB systems.

We propose applying some existing semiautomatic beam switching device requirements to ADB systems: Manual override (S9.4.1.2); fail safe operation (S9.4.1.3); and automatic dimming indicator (S9.4.1.4). These are requirements that apply today to semiautomatic beam switches.

We also propose adopting additional operation requirements that do not have analogs in the current semiautomatic beam switching device requirements; most of these are also part of SAE J3069. We propose to require the following:

- The ADB system must be capable of detecting system malfunctions (including but not limited to sensor obstruction).
- The ADB system must notify the driver of a fault or malfunction.
- If the ADB system detects a fault, it must disable the system until the fault is corrected.
- The system must produce a base lower beam at speeds below 25 mph. As the primary purpose of the ADB is to provide additional light down the road at high speed, the system is not needed at lower speeds. For speeds below 25 mph, it may be likely that the potential disbenefits from glare outweigh the potential benefits from the additional headlamp illumination.

Although we propose requiring a telltale informing the driver when the ADB system is activated (the automatic dimming indicator requirement in S9.4.1.4), we have tentatively decided not to require telltales indicating the type of beam (upper or lower) the ADB system is providing. We have tentatively decided not to follow the approach of ECE Regulation 48, which requires the upper beam telltale be used to indicate ADB activation, because we consider the ADB adaptive beam to be a lower beam if there are vehicles on the roadway to which the beam must adapt. We also do not require a telltale indicating an enabled ADB system is projecting an augmented lower beam. We believe providing the driver with a visual indication of the type of beam (upper or lower) an ADB system is providing is not necessary for safe driving and, if present, may result in the driver making unnecessary glances at the instrument panel instead of monitoring the roadway. We also propose revising the existing upper beam indicator requirement in S9.5 to state that the upper beam indicator need not activate when the ADB system is activated (and the ADB telltale is activated). This is consistent with SAE J3069. OEMs would be free to devise supplemental telltales/messages. In all of these, we follow the approach taken in SAE J3069.[79]

We seek comment on these choices. Our intent is to ensure that ADB systems operate robustly, while at the same time not unduly restricting manufacturer design flexibility. We also note that Table I–a of FMVSS No. 108 requires the "wiring harness or connector assembly of each headlighting system must be designed so that only those light sources intended for meeting lower beam photometrics are energized when the beam selector switch is in the lower beam position, and that only those light sources intended for meeting upper beam photometrics are energized when the beam selector switch is in the upper beam position, except for certain systems listed in Table II." This might affect design choices for the headlight and/or ADB controls. It might mean that the headlight and ADB controls could not be designed so the ADB system is activated when the beam selector switch is in the lower beam position—the ADB system might, if no other vehicles are present, be projecting the upper beam, which could mean that upper beam light sources are activated when the beam selector switch is in the lower beam position. We seek comment on the effect of this requirement on ADB systems, and whether it needs to be amended, and if so, how.

We are not proposing to subject the switch controlling the ADB system to any physical test requirements (*e.g.,* vibration requirements, humidity requirement, etc.). We are not extending current device test requirements for

[79] S6.8 and discussion at p. 2.

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semiautomatic beam switching devices [80] to ADB systems because those requirements date from the 1960s and do not appear to usefully extend to modern ADB technologies. We also are not proposing any new physical test requirements. We believe market forces will ensure an ADB system's switching device will operate robustly. We are, however, proposing requiring the ADB system to provide malfunction detection and notification and fail-safe operation. We seek comment on whether we should specify physical test or additional device test requirements.

In addition, other requirements in FMVSS No. 108 applying to headlamps will apply to ADB systems. ADB systems, as part of the required lighting system, would be required to comply with, for example, the Table I requirements, such as color (S6.1.2) and the steady-burning requirement (except for signaling purposes, and except for the automatic switching from upper beam to lower beam stimulated by the appearance of an oncoming or preceding vehicle), and any other provisions in FMVSS No. 108 that would apply to ADB systems by virtue of their being part of the required headlighting system (as we have tentatively concluded that they are).[81] We asked for comment in Section VI above for any other regulatory provisions that might affect ADB systems that we should consider amending.

iv. Retention of Existing Requirements for Semiautomatic Headlamp Beam Switching Devices Other Than ADB

The proposal retains the existing semiautomatic beam switching requirements for beam switching devices other than ADB (*i.e.*, beam switching devices that switch only between an upper beam and a single lower beam). These requirements have been in the standard for several decades, and while they might be updated, the focus of this rulemaking is on amending the current requirements to allow the adoption of ADB systems.

b. Test Procedures

i. Introduction

This section explains how we propose to test an ADB system to determine whether it complies with the photometric glare limits we are proposing as a performance requirement. We propose to test the ADB system in a dynamic road test, in a select number of driving scenarios and road configurations.[82] As noted earlier, the existing headlamp photometric requirements, including the requirements that regulate glare, are component-level requirements, and testing for compliance with them is conducted on the headlamp in a laboratory. We tentatively believe a dynamic road test is necessary to ensure, to a reasonable degree of confidence, that an ADB system meets minimum safety requirements for the prevention of glare. Because the ADB system relies on a combination of sensors/cameras, controller units, and headlamps that must all work together, the Agency tentatively concludes a dynamic compliance test is essential for evaluating ADB performance.

Below we discuss the proposed test procedures in detail. The proposed procedures involve equipping an FMVSS-certified vehicle with photometers (a "stimulus vehicle") to measure the amount of glare produced by the ADB-equipped vehicle being tested for compliance ("test vehicle"). With respect to the track on which we would test vehicles, we propose specifying relatively broad ranges of conditions, with a limited number of driving scenarios to maintain a practical and efficient test while also reflecting real-world conditions to which an ADB system would need to adapt to perform adequately. The test track may include straight and curved portions but no intersections. For curved sections, we propose allowable radii of curvature. The ADB systems we tested were unable to prevent glare to any measurable degree better on hilly roads than a typical lower beam headlamp. Accordingly, the longitudinal slope (grade) cannot exceed 2% to maintain useful alignment with headlamps. While we encourage continued development of the technology to reduce glare below the current lower beam on hilly roads, we are not proposing such a requirement today. We are proposing realistic vehicle speeds, appropriate for the radii of curvature we have specified.

ii. Test Vehicle and Stimulus Vehicle

In later sections of this preamble, we discuss proposed maneuvers of the stimulus and ADB test vehicles. Here, we discuss the stimulus vehicles we propose to use in testing.

1. Proposal

We propose to use as a stimulus vehicle any FMVSS-certified vehicle satisfying the following criteria: (1) Of any FMVSS vehicle classification excluding trailers, motor-driven cycles, and low-speed vehicles; (2) of any weight class; (3) of any make or model; (4) from any of the five model years prior to the model year of the test vehicle; and (5) subject to a vehicle height constraint. These criteria, and alternatives we are considering, are discussed in more detail below.

Vehicle Classification

We propose to use vehicles of any FMVSS classification other than trailers, motor-driven cycles, and low-speed vehicles: passenger cars, buses, trucks, multipurpose passenger vehicles, and motorcycles. An ADB system should be able to function so as to not glare a broad range of FMVSS-certified vehicles. We do not believe it would be difficult for an ADB system to identify and shade different vehicle types because the image recognition technology will likely focus on headlight and taillight patterns and locations. While the FMVSS do not regulate vehicle width, FMVSS No. 108 does regulate the range of permissible mounting heights for front and rear lamps, based on the type of vehicle; this should help aid detection.

Weight

We propose using vehicles of any gross vehicle weight rating (GVWR). SAE J3069 similarly uses fixtures based on light and heavy vehicle applications. Again, we see no reason why an acceptable ADB system should not be able to recognize and shade both large and small vehicles as these vehicles will be encountered in the real world.

Make and Model

We propose using any make or model of vehicle (that meets the other criteria). We alternatively considered specifying a list of eligible test vehicles by make and model spanning a range of manufacturers and vehicle types. The list would be included as an appendix in FMVSS No. 108. Vehicles included on the list would comprise a relatively large percentage of vehicles sold in the United States; for example, the list could be based on vehicle and sales data from Ward's Automotive Yearbook. Under this specification, the Agency could use any vehicle on the list from the preceding five model years. We have tentatively decided not to adopt this

[80] FMVSS No. 108 S14.9.3.11.

[81] Other examples include, but are not necessarily limited to, the following: S10 (headlighting system requirements); S12 (headlamp concealment device requirements); S13 (replaceable headlamp lens requirements); and S14.6 (headlamp physical test requirements and procedures).

[82] As with all the FMVSSs, the proposed test procedures are the procedures that NHTSA would use in performing compliance testing. Vehicle or equipment manufacturers would not be required to use these testing procedures to certify their vehicles. They may certify their vehicles using other means as long as they exercise due care in making that certification.

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approach because we believe an ADB system should recognize and shade a wide variety of vehicles. However, we seek comment on this alternative approach. Are there certain makes or models an ADB system should not be expected and required to detect? If so, what is the basis for such a determination, and how does it satisfy the need for safety as well as practicability?

Model Year

We believe limiting ourselves to the preceding five model years strikes a reasonable balance between the need for safety and practicability.

Vehicle Height Constraint

While we propose potentially using a relatively broad range of vehicle types, weights, makes, and models, we propose to constrain the set of vehicles eligible as test vehicles by vehicle height. The height constraint is based on the proposed specification for where the photometric receptor head(s) to measure oncoming glare will be placed on the windshield of the stimulus vehicle (see Section VIII.b.ii.3.a below). They may be mounted anywhere within a specified range on the windshield (roughly corresponding to where the driver's eyes would be), subject to a height constraint: The photometer may be placed no higher or lower than a specified height range (measured with respect to the ground). The ranges are based on data and studies of driver eye heights for different types of vehicles. If it is not possible to mount the receptor head(s) within the specified range on a candidate stimulus vehicle, then that vehicle would not be eligible for use as a stimulus vehicle. This photometer receptor head placement constraint effectively acts as a constraint on vehicles that may be used as stimulus vehicles and excludes vehicles that ride unusually high or low. We are proposing this constraint because we recognize it may be difficult or impossible to design a headlighting system accommodating such outlier vehicles. The existing Table XIX lower beam photometry requirements are such that low-to-the-ground vehicles may be subject to glare even by a compliant lower beam. We would also constrain ourselves by not using unusually high vehicles to ease potential testing burdens on manufacturers.

Summary

We tentatively believe this broad range of stimulus vehicles is reasonable to adequately ensure that an ADB system functions robustly and avoids glaring other drivers; we are concerned about a test procedure effectively permitting an ADB system designed to accommodate only a narrow range of oncoming or preceding vehicles. The purpose of the stimulus vehicle is to elicit headlamp beam adaptation by an ADB system and test whether the ADB system recognizes oncoming and preceding vehicles and appropriately limits the amount of light cast on these vehicles to ensure that they are not glared. This requires an ADB system be able to appropriately detect and identify light coming from another vehicle and dynamically shade that vehicle. An ADB system must be able to recognize multiple possible configurations of headlights and taillights, on vehicles of different size and shape (within a reasonable range).

We tentatively believe it would be practicable for a manufacturer to design an ADB system to recognize and shade any vehicle satisfying the proposed selection criteria. Although we are proposing a relatively broad range of eligible stimulus vehicles, the lighting configurations an ADB system would have to recognize are not unbounded. Front and rear lighting designs are limited by the requirements of FMVSS No. 108 and realities of vehicle design. Mounting heights, number, color, and locations of vehicle lighting are constrained by requirements set out in Table I of FMVSS No. 108. For example, headlamps must be white and mounted at the same height symmetrically about the vertical centerline, as far apart as practicable, and mounted at a height of not less than 22 inches nor more than 54 inches. Additionally, while we are proposing a broad array of makes and models as test vehicles, there is a limited, and not exceptionally large, number of makes and models of vehicles offered for sale in the United States every year. For example, in Model Year 2017, approximately 420 makes/models of passenger cars, trucks, vans, and SUVs were offered for sale. The set of vehicles eligible to be used as test vehicles will be further limited by the height constraint we are proposing.

We seek comment on the proposed vehicle selection criteria. Do the criteria define a set of stimulus vehicles that is so large as to be impracticable or unnecessary? If so, in what specific ways would manufacturers find them impracticable, or why are they unnecessary (*i.e.*, how could the Agency be confident that glare prevention could be adequately ensured with a smaller set of possible stimulus vehicles)? Are the alternative criteria mentioned above preferable, and if so, why? Are there other vehicle selection criteria that would result in a smaller set of eligible stimulus vehicles but that would still be sufficient to adequately discriminate between a robust ADB system and a less robust ADB system?

2. Alternative: Test Fixtures

We also considered using test fixtures instead of vehicles for the purpose of eliciting an ADB response as part of a compliance test. SAE J3069 specifies stationary test fixtures (structures intended to simulate the front or rear of an actual vehicle) in place of actual vehicles. It specifies four test fixtures: An opposing car/truck fixture; an opposing motorcycle fixture; a preceding car/truck fixture; and a preceding motorcycle fixture. The fixtures are fitted with lamps simulating headlamps and taillamps. For headlamp representations, it specifies a lamp projecting 300 cd of white light in a specified manner and angle. For the taillamp representations, it specifies lamps emitting no more than 7 cd of red light in a specified manner and angle. The fixtures are fitted with photometers positioned near where a driver's eyes would be to measure the light from the ADB test vehicle.[83] The lamp and photometer locations are based on "median location values provided by [the University of Michigan Transportation Research Institute]."[84] SAE specifies test fixtures to reduce test variability and because it considers stationary fixtures as a "worst case since some camera systems utilize opposing or preceding vehicles movement within a scene to identify them as vehicles instead of other road objects, such as reflectors on the side of the road."[85] There was also a "concern that if the actual lower beam headlamps were used on the opposing vehicle test fixture the large gradients present in typical lower beam patterns would cause unnecessary test variability."[86]

We are not proposing to use test fixtures because we have tentatively concluded they may not be sufficient to ensure that an ADB system operates satisfactorily in actual use. Using stationary test fixtures as opposed to dynamic actual production vehicles has the advantage of relative simplicity and ease of testing. However, the drawback is that it is not realistic. Test fixtures may encourage an ADB system designed to ensure identification of test fixtures rather than actual vehicles. This may not adequately ensure that the system

[83] SAE J3069 5.5.2 and Figures 1 and 2 (opposing vehicle fixture); 5.5.3 and Figures 3 and 4 (preceding vehicle fixture).

[84] SAE J3069, p. 3.

[85] SAE J3069, p. 3.

[86] SAE J3069, p. 4.

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performs satisfactorily when faced with a wide range of different vehicles equipped with lighting differing from the test fixtures. In addition, to the extent that test fixtures differ in appearance from actual vehicles, an ADB system would have to be programmed to recognize them, which in practice might make it difficult to tune out non-vehicle objects confronting the system in actual use. Regarding gradients in typical headlamp beam patterns, we tentatively believe this will only affect the repeatability of the test if the reaction by the ADB system changes based on this difference. If this is the case, the ADB system will have this issue in actual use, and this should not be considered variability attributable to the test, but a failing of the ADB system.

We are also not necessarily confident that stationary fixtures with lamps represented as specified in SAE J3069 represent a worst-case scenario. Some ADB systems may have more difficulty detecting moving dim lights or moving lights spaced a certain width apart. The Agency welcomes any data relating to this. In addition, we seek comment on the extent to which narrowly defined lamps can be used to establish performance requirements that reasonably ensure an ADB system will recognize and adapt appropriately to the wide range of lighting configurations permitted under FMVSS No. 108. For instance, the minimum intensity allowed for a taillamp is 2.0 cd at H–V and as low as 0.3 cd at an angle of 20 degrees. These values are considerably lower than the 7.0 cd lamp specified in SAE J3069. Using stationary test fixtures would likely reduce test variability. However, we tentatively believe that the variability attributable to the proposed procedure would be within acceptable limits considering the previously described necessity of vehicle-level testing as demonstrated by NHTSA's research. As discussed below in Section VIII.c, the variability the Agency observed in the test results between a stationary lower beam and a moving test vehicle lower beam (most applicable in the straight approach maneuver) seemed to primarily be caused by the moving test vehicle not the moving stimulus vehicle.

3. Photometer Placement

The photometer measures the amount of light cast by the ADB test vehicle falling on the stimulus vehicle. Our general approach is to place the photometer[87] near where the driver's eyes would be (to measure glare to oncoming vehicles) or near where light would strike an inside or outside rearview mirror (to measure glare to preceding vehicles).

a. Oncoming Vehicles

Here the approach is to measure light cast near where the driver's eyes would be. Below we explain our proposal, as well as several alternatives.

Proposal

We propose to specify the position of photometers with respect to the X, Y, and Z coordinates[88] (*i.e.*, the longitudinal, lateral, and vertical placement of the photometers). With respect to the longitudinal position, we propose to mount the photometer(s) outside the vehicle, forward of the windshield and rearward of the headlamps. Measuring headlight illuminance in front of the windshield is consistent with the proposed glare limits; they are derived from the current glare test points, which apply to light coming from a headlamp and do not take into account effects related to the windshield glass. If the photometer were placed behind the windshield, test results might depend on properties of the windshield, which is undesirable because the purpose of the test is to measure ADB system performance.

With respect to the lateral and vertical positions of the photometer(s), we are proposing specifying a range of permissible positions.

With respect to the lateral position of the photometer, we propose locating the photometer anywhere from the longitudinal centerline of the stimulus vehicle over to and including the driver's side A-pillar.

With respect to the vertical position of the photometer, we propose placing it anywhere from the bottom of the windshield to the top of the windshield, subject to an upper bound and a lower bound. These upper and lower bounds, which differ based on vehicle classification and weight, are set out in the proposed regulatory text and are reproduced in Table 4. If it is not possible to place a photometer on a candidate measurement stimulus vehicle so the photometer was both between the top and bottom of the windshield and within the applicable range in Table 4, then that vehicle would not be eligible for use as a stimulus vehicle.

TABLE 4

Vehicle classification/weight	Mean	Height range (m)	
		Lower bound	Upper bound
Passenger Cars	1.11	1.07	1.15
Trucks, buses, MPVs (light)	1.42	1.26	1.58
Trucks, buses, MPVs (heavy)	2.33	1.99	2.67
Motorcycles	1.43	1.30	1.66

"Light" means vehicles with a GVWR of 10,000 lb. or less. "Heavy" means vehicles with a GVWR of more than 10,000 lb. Heights are measured from the ground.

[87] Or, perhaps more accurately, photometric receptor heads, if, for example, the photometer is configured with multiple receptor heads, as was the case in NHTSA's testing. For ease of exposition, the discussion in this document simply refers to the "photometer" to refer to the test equipment used to detect the light emitted from the ADB system. In addition, we may use multiple photometers or receptor heads simultaneously.

[88] *See* SAE J1100 FEB2001, Motor Vehicle Dimensions.

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The ranges for passenger cars and light trucks, buses, and MPVs are from a 1996 University of Michigan Transportation Research Institute (UMTRI) study estimating mean driver's eye heights based on a sample of high-sales volume vehicles and drivers.[89] The range for heavy trucks, buses, and MPVs is from a 1990 study based on a sample of heavy goods vehicles in a 1989 roadside survey in the United Kingdom.[90] The ranges we are proposing are the two standard deviation ranges.[91] These are consistent with the photometer heights specified in SAE J3069 for the opposing vehicle fixtures. SAE J3069 specifies heights of 1.1 m and 2.2 m for the photometers used to measure oncoming glare to drivers of passenger cars and trucks, respectively. While SAE J3069 specifies a point, not a range, the points it specifies for the passenger car and truck driver eye heights are based on the same means we used to construct the height ranges for passenger cars and heavy trucks/buses. (SAE J3069 does not distinguish between heavy and light trucks, and appears to use a mean for truck driver eye height that is a slight downward adjustment of the heavy truck mean reported in the Cobb study).

The height range for motorcycles was determined as follows. The opposing motorcycle test fixture specified in SAE J3069 locates the photometer coincident with the rider's eye point, 1.3 m above the ground. This appears to have been based on the 5th percentile motorcycle rider eye height of 1.35 m reported in a study that examined motorcycle rider eye heights in Malaysia.[92] We propose this as the lower bound for the vertical height of the photometer. For the upper bound, we propose using 1.66 m, which is based on a two-standard deviation range.[93]

We tentatively believe that the proposed specification for the placement of the photometers meets the need for safety and is practicable. It defines a bounded area approximating the location of the driver's (or rider's) eyes. Unlike a specification for an eye ellipse,[94] which defines a smaller area more precisely targeting where the driver's eyes would likely be located, the larger area we specify provides a margin for safety and is easier to locate. Given that ADB is currently designed to shade an entire approaching or preceding vehicle, we believe focusing on a small area such as that of an eye ellipse is not necessary. Instead, "the expectation is that ADB will reduce any glare producing light toward and on the full width of opposing and preceding vehicles, thereby providing benefit to all occupants in the vehicle."[95] However, we propose to subject the vertical placement of the photometer to a lower bound because we recognize it may be difficult to design an ADB system to prevent glaring extremely low-riding vehicles with correspondingly low driver eye heights; we recognize that because of the low height, even an FMVSS No. 108-compliant lower beam might glare such a low-riding driver. We are proposing an upper bound on photometer placement to limit the conceivable test locations; we also do not anticipate ADB systems would produce high levels of illumination at heights above the ranges we are proposing. At the same time, we believe a two-standard deviation range captures enough variation to require the design of robust ADB systems. We also believe specifying these bounds will ensure tests are not unduly stringent. If a candidate stimulus vehicle is such that there is no position between the top and bottom of the windshield that would be within these bounds, then that vehicle would not be eligible for use as a stimulus vehicle.

We seek comment on the proposed specifications for photometer placement. In particular, we seek comment on whether the proposed height range is necessary, and if so, whether the proposed specification is sound.

Alternatives to Proposal

We also considered alternative procedures for determining the lateral and/or vertical position of the photometer(s) to measure oncoming glare. We discuss these below. Note that these are not alternatives for determining the longitudinal position of the photometer. In addition, for all of these alternatives, the vertical position of the photometer(s) would be subject to the upper and lower bounds proposed above.

Alternative 1

We considered specifying the lateral and vertical position of the photometer by using a test procedure based on that currently used to locate the approximate eye position of a 50th percentile male in compliance testing for the FMVSS No. 111 rear visibility field of view and image size requirements. FMVSS No. 111 requires, among other things, a visual display of an image of an area behind the vehicle and specifies certain requirements for the image. The field of view and image size test procedures locate where eyes of a typical driver would be. More specifically, they locate the midpoint of the eyes of a 50th percentile male. The test procedure specifies the eye midpoint by using the H-point as a point of reference. The H-point is used in several other NHTSA standards[96] and represents a specific landmark near the hip of a 50th percentile adult male positioned in a vehicle's driver seat. It has been used by NHTSA as well as other organizations in

[89] Michael Sivak, *et al.* 1996. The Location of Headlamps and Driver Eye Positions in Vehicles Sold in the U.S.A. UMTRI–96–36. University of Michigan, Transportation Research Institute, p. 9.

[90] J. Cobb. 1990. Roadside Survey of Vehicle Lighting 1989. Research Report 290. Department of Transport, Transport and Road Research Laboratory (cited and discussed in Michael Sivak, *et al.* 1991. The Influence of Truck Driver Eye Position on the Effectiveness of Retroreflective Traffic Signs. UMTRI–91–35. University of Michigan, Transportation Research Institute, p. 8.).

[91] The American Association of State Highway and Transportation Officials (AASHTO) uses similar values for driver's eye height for measuring sight distances. A Policy on Geometric Design of Highways and Streets. 2011. AASHTO (hereinafter "AASHTO Green Book"). It recommends 1.08 m for passenger vehicles and 2.33 m for large trucks (and notes a range of 1.8 to 2.4 m for large trucks). *Id.* pp. 3–14. The AASHTO values are based on a 1997 study by the Transportation Research Board, which estimated the values for passenger cars, multipurpose vehicles, and heavy trucks. Daniel B. Fambro, *et al.* 1997. NCHRP Report 400: Determination of Stopping Sight Distances. Transportation Research Board, National Research Council, National Cooperative Highway Research Program. The driver eye height values used by AASHTO for passenger cars and large trucks appear to be the 10th percentile values reported in the NCHRP report for passenger cars and heavy trucks, respectively. NCHRP Report 400, pp. 44–45 (Tables 31 and 33). The mean values in the NCHRP report are 1.15 m (passenger cars), 2.45 m (large trucks), and 1.48 m (MPVs). Since these estimates are based on a dynamic road survey conducted (largely) in 1993, they are based on older vehicles than the MY 1996 vehicles surveyed by UMTRI. The heights found by UMTRI are lower than in the NCHRP report; this is consistent with the observation that driver eye heights have tended to decrease over time. *See* AASHTO Green Book, p. 3–14.

[92] Seyed Davoodi *et al.* 2011. Motorcycle Characteristics for Sight Distance Investigation on Exclusive Motorcycle Lanes. Journal of Transportation Engineering, 137(7): 492–495.

[93] Specifically, this is based on the mean of 1.43 m reported in Davoodi *et al* and the standard deviation reported in another paper (.117 m). *See* Terry Smith, John Zellner & Nicholas Rogers. 2006. A Three Dimensional Analysis of Riding Posture on Three Different Styles of Motorcycle. International Motorcycle Safety Conference, March 2006. This paper compares the riding posture (using anatomical landmarks) of a sample of human test subjects to the posture of the Motorcycle Anthropometric Test Dummy (MATD). The paper reports, among other things, the standard deviation of the vertical location of the test subjects' left infraorbitale (a point just below the eye) relative to the infraorbitale of the MATD of .117 m. In other words, the study reports the standard deviation of the vertical location of the infraorbitale relative to a fixed point.

[94] SAE J941, Motor Vehicle Drivers' Eye Locations.

[95] SAE J3069, p. 3.

[96] *See, e.g.*, FMVSS No. 208, S10.1; FMVSS No. 210, S4.3.2.

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the context of visibility measurement. SAE J826 JUL95 defines and specifies a procedure, including a manikin ("H-point manikin"), for determining the exact location of the H-point in a vehicle; it specifies the H-point in relation to the hip location of a driver in the driver seating position. The rear visibility test procedure uses the J826 manikin and procedure to locate the H point. It then uses anthropometric data from a NHTSA-sponsored study of the dimensions of 50th percentile male drivers [97] to locate the midpoint between the driver's eyes.[98] In practice, a testing laboratory typically uses an H-point manikin fitted with a camera (which is needed for the field of view and image size tests) positioned at the driver's eye midpoint.

We considered a simplified version of this procedure to determine the approximate vertical and lateral position (the Z and Y coordinates) of the expected eye position of a 50th percentile male driver. The driver's seat positioning test procedure in S14.1.2.5 and part of the test reference point procedure (S14.1.5(a)) in FMVSS No. 111 locates the center of the forward-looking eye midpoint with respect to the H-point. We considered using the Z and Y coordinates of the forward-looking eye midpoint to specify the position of the photometer in front of the windshield. This procedure would locate the photometer approximately where the eyes of an average male driver would be. Mounting the photometer at different but nearby locations (*e.g.*, a location corresponding to the forward-looking eye midpoint of a 5th percentile female) would add additional testing burden while likely not affecting the outcome of the test. This alternative test procedure would appear to be practicable. The H-point machine is a fairly standard piece of laboratory test equipment used in other FMVSS and SAE standards. Compared to the proposed test procedure, there would likely be some additional work involved in positioning the manikin, but this may not add an exceptional amount of cost or time to the test, particularly if the laboratory performing the test already had an H-point machine. This alternative might be preferable to the proposed option if it were determined ranges utilized by the proposed option did not have a sound basis.

Alternative 2

As another alternative for specifying the lateral and vertical position of the photometer(s), we considered obtaining from the manufacturer of the stimulus vehicle the coordinates of the midpoint of the 50th percentile male's drivers' eyes. We believe most vehicle manufacturers would have this information and could supply it to NHTSA. The purpose of this would be to save the Agency time in doing the test, perhaps if an H-point machine were not readily available. While there would be some difference between the photometer location compared to Alternative 1, we believe such relatively small changes would not meaningfully affect test outcomes. If a manufacturer desired to conduct testing following NHTSA's test procedures, it could use a stimulus vehicle it manufactures, or, if it desired to use a stimulus vehicle manufactured by another manufacturer, it could potentially obtain information from the manufacturer of that vehicle.

Alternative 3

We also considered, as an alternative for locating the photometer with respect to the Z and Y axes, using SAE J941 JAN2008, Motor Vehicle Divers' Eye Locations. This document describes a procedure for locating a mid-centroid driver's eye ellipse. We tentatively concluded that, for purposes of compliance testing, J491 would not provide an easy enough to follow procedure; we believed that it would be easier to use the H-point machine instead.

Alternative 4

As a final alternative for locating the photometer laterally, we considered specifying the test procedure such that NHTSA could place the photometer anywhere from the driver's side A pillar up to and including the passenger side A-pillar. This would give an extra margin of safety with respect to glare directed at the driver and would also ensure passengers are not glared. Or, photometers could be positioned at the geometric center of the windshield, which would limit the range of testing.

We seek comment on the desirability of each of these options, whether we should adopt one, or multiple options, and the relative merits of each.

b. Preceding Vehicles

For preceding vehicles, the safety concern is the ADB system could glare the driver by shining excessive light onto the inside or outside rearview mirrors. To measure glare on the outside rearview mirrors, we propose placing the photometer anywhere against or directly adjacent to the mirror's reflective surface. To measure glare on the inside rearview mirror, we propose placing the photometer on the outside of the rear window, laterally and vertically aligned with the interior mirror. We are not proposing more detailed procedures for placing the photometers because the locations of the mirrors themselves largely determine the placement of the photometer, and we do not expect test results to be affected by small variations in the placement of the photometer. We seek comments on this aspect of the proposal.

4. Photometers and Photometric Measurements

We propose that in compliance testing, NHTSA would use a sampling rate of at least 200 Hz when recording test data. We would sample over all the distance ranges for which we are proposing a corresponding glare limit. Illuminance meter and data acquisition equipment would be configured and any necessary steps would be taken to isolate measurement of the light emitted by the ADB test vehicle. We seek comment on the appropriateness of this minimum sampling rate, as well as whether a maximum sampling rate should be specified and, if so, what it should be. We also seek comment on whether there are other aspects of the photometric equipment or measurements that should be specified.

For each test run, illuminance data would be continuously recorded as the ADB vehicle approached the stimulus vehicle through the range defined for the specific test scenario being run. This inter-vehicle distance is measured from the intersection of a horizontal plane through the headlamp light sources, a vertical plane through the headlamp light sources and a vertical plane through the vehicle's centerline to the forward most point of the relevant photometric receptor head mounted on the stimulus vehicle.

In determining the set of recorded illuminance values we would look at within each distance interval to determine compliance, we propose to use the recorded values starting with (and including) the first recorded value up to and including the last recorded illuminance value in each distance range. Any recorded illuminance values in a distance interval greater than the applicable glare limit for that distance would be considered a test failure, provided the value is not a small spike. Values above the applicable glare limit lasting no longer than 0.1 sec. or over a distance range of no longer than 1 m would not be considered test failures. This allows for electric noise in the

[97] L.W. Schneider, D.H. Robbins, M.A. Pflüg, & R.G. Snyder. 1985. Anthropometry of Motor Vehicle Occupants; Volume 1-Procedures, Summary Findings and Appendices. National Highway Traffic Safety Administration, DOT 806 715.

[98] *See generally* 75 FR 76232.

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photometers as well as momentary pitch changes of the test and stimulus vehicles caused by bumps in the test track.

The proposal differs from SAE J3069. For purposes of determining whether an ADB system complies with the glare limits, SAE J3069 considers only illuminance values recorded at distances of 30, 60, 120, and 155 meters, instead of sampling multiple illuminance values within these distance ranges.[99] Because an oncoming or preceding driver could be glared anywhere from 15 m to 220 m, and because the real test of an ADB system's performance is how it operates over the full distance range within which it may be glaring other drivers, we tentatively conclude it is necessary to sample illuminance values throughout this full range, and not simply evaluate ADB system performance at the four distance points at which the derived glare limit changes. Because we are sampling illuminance within these ranges, there is no need to use interpolation. The Agency would look only at these recorded values and not interpolate any values in evaluating compliance. We seek comment on these aspects of the proposal, in particular on whether there are any safety impacts in choosing the proposed test over the SAE approach.

iii. Considerations in Determining Compliance With the Derived Glare Limit Values

The lower beam photometric test points in Table XIX of FMVSS No. 108, from which the proposed glare limits are derived, apply to direct illumination from a headlamp. They do not include ambient light or reflected light from the road surface or signs. Ambient light refers to light emitted from a source other than the ADB system. This includes moonlight, light pollution from nearby buildings, or light coming from the stimulus vehicle. Reflected light refers to light from the ADB vehicle's headlights reflected off the road or other surface into the photometer(s) on the stimulus vehicle.

We propose to account for light from these sources in a couple of ways. To minimize ambient light, we propose that testing occur when the ambient illumination recorded by the photometers is at or below 0.2 lux.[100] We are also proposing the test only be conducted on dry pavement as well as pavement that is not bright white to avoid intense roadway reflections. Nevertheless, some degree of ambient light is unavoidable. Accordingly, in testing compliance the Agency will zero the photometers with the stimulus vehicle's headlighting system on and the stimulus vehicle in the orientation it will be during the test (for example, facing east). If the test involves a curve such that the orientation of the stimulus vehicle changes during the test, the photometers will be zeroed in the direction of the maximum ambient light.

There are more finely grained ways to measure ambient illumination. For driving scenarios in which the stimulus vehicle is moving, we could, for example, dynamically measure ambient illuminance by driving the stimulus vehicle over the test course and continuously recording ambient illuminance over this run. We have tentatively decided this would be unnecessary because we are not proposing to use any roadway illumination. We do not anticipate ambient illumination will vary significantly at different points on a test course section used for a particular driving scenario. We have tentatively decided there is no need to further adjust the measured illuminance values to account for reflected light from the ADB headlights.

We note that FMVSS No. 108 is unusual among the FMVSSs because it requires that lighting equipment be "designed to conform" to relevant requirements, as opposed simply to comply with relevant requirements. As we have explained in the past, when NHTSA initially proposed in 1966 that lamps "comply" with FMVSS No. 108, industry represented that it could not manufacture every lamp to meet every single test point without a substantial cost penalty unjustified by safety. NHTSA accepted this argument. In adopting the standard, the Agency specified that lamps be designed to comply or designed to conform with the applicable photometric specifications. On a number of occasions since, NHTSA has stated that it will not consider a lamp to be noncompliant if its failure to meet a test point is random and occasional. Thus, historically, there has never been an absolute requirement that every motor vehicle lighting device meet every single photometric test point to comply with Standard No. 108.[101] Lighting equipment design, technology, and manufacturing have evolved and advanced since the late 1960's when the Agency initially adopted the design to conform language, and it may be arguable whether the Agency would come to the same conclusion were it to revisit this issue. Such matters are beyond the scope of this rulemaking. We simply note that we are proposing to extend the design to conform language of the current FMVSS No. 108 to the proposed requirements.

There are other adjustments to the measured illuminance values we could potentially make, but we have tentatively decided not to propose. NHTSA requests comment on the following:

- Should pitch correction be addressed directly, or are the momentary spike provisions enough to meet the goals of this rulemaking?
- SAE J3069 allows a 2.5 sec reaction time (*i.e.*, a glare limit may not be exceeded for more than 2.5 sec), motivated by the "sudden appearance of an opposing or preceding vehicle due to a cresting a hill, a vehicle entering a roadway, etc." Should the Agency consider such a reaction time requirement in the regulation?
- Should the Agency specify specific photometry equipment and/or filtering based on the test vehicle's light source technology? Should the Agency specify different equipment to test HID, halogen, LED, or pulse width modulated headlamps?

iv. Additional Test Parameters

1. Test Scenarios

We are proposing a variety of different scenarios the Agency would be able to run to test for compliance. Scenarios would be specified in the regulatory text. For each scenario, we specify speeds of the ADB and stimulus test vehicles, the radius of curvature of the track, the superelevation, the orientation of the ADB and stimulus test vehicles, and the particular vehicle maneuver tested. Values proposed for speed, radius of curvature, and superelevation are consistent with a standard formula used in road design specifying the relationship between these parameters. The formula, referred to as the simplified curve formula, is

$$0.01e + f = \frac{V^2}{15R},$$

where f is the coefficient of friction, V is the vehicle speed, R is the radius of curvature, and e is superelevation.[102]

The proposal specifies vehicle speeds of up to 70 mph, depending on whether the test track is straight or curved (and how tight the curve is). We propose to

[99] If there is no illuminance value recorded at a specified distance, SAE J3069 specifies an interpolation procedure to generate an illuminance value at that distance.

[100] *See* SAE J3069 at 5.5.2.1, 5.5.3.1 ("No other vehicle lighting devices shall be activated or any retro-reflective material present and care should be taken to avoid other sources of light, reflected or otherwise.").

[101] *See* 62 FR 63416 (Nov. 28, 1997).

[102] AASHTO Green Book, pp. 3–19 to 3–20.

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use speeds up to 70 mph when testing on a straight track. We believe an upper limit of 70 mph is reasonable because freeways and other arterials frequently have speed limits this high. We believe that for an ADB system to operate at a sufficient level of safety it should be able to operate at these speeds, both because these speeds are typical of real-world driving, as well as because safety concerns regarding glare are magnified at higher speeds.

We propose using a straight track or a track with a radius of curvature from 320–380 ft. (for vehicle speeds of 25–35 mph); 730–790 ft. (for vehicle speeds of 40–45 mph); and 1100–1300 ft. (for speeds of 50–55 mph). The first range of radius of curvature corresponds to (approximately) the smallest radius of curvature appropriate for a vehicle traveling 25–35 mph; these speeds roughly correspond to the minimum speed for which we propose to allow ADB activation. The second range of radius of curvature roughly corresponds to the higher ADB minimum activation speeds of some of the ADB-equipped vehicles the Agency tested. Finally, to evaluate ADB performance at higher speeds, we are proposing an 1100–1300 ft. radius taken at 50–55 mph. We tentatively believe it is important to include actual curves because curves may present engineering challenges to ADB systems. For example, in oncoming situations, a curve presents an engineering challenge in that the opposing vehicle appears from the edge of the field of view at a close distance; in a tight curve, an oncoming vehicle will enter the camera field of view at a closer distance than in a larger-radius curve. Performing adequately on large-radius curves at relatively high speeds presents a slightly different engineering challenge than performance on tight curves at lower speeds.

We also propose superelevation (*i.e.*, the degree of banking of the track) of 0 to 2%. We attempt to minimize the degree of banking because photometry design as well as the existing and derived glare limits are based on flat surfaces.

We are proposing three basic maneuvers for testing compliance. These are oncoming (where the ADB and stimulus vehicles approach each other traveling in opposite directions); same direction/same lane (where the stimulus vehicle precedes the ADB vehicle in the same lane); and same direction/passing (where the stimulus vehicle begins behind the ADB vehicle, in the adjacent lane, and then passes the ADB vehicle from either the left or the right). During each of these maneuvers, each vehicle would be driven within the lane and would not change lanes. For each of these types of maneuvers, we specify the stimulus vehicle speed, ADB vehicle speed, radius of curvature (if testing on a curve), and superelevation with which the Agency may test.

The proposal differs significantly from SAE J3069 in several respects. First, as discussed above in Section VIII.b.ii, we are proposing to test with actual vehicles and not simply test fixtures. Second, this proposal effectively tests at higher speeds than SAE J3069. SAE J3069 specifies a minimum speed (above the ADB activation threshold speed) but does not specify maximum speed. Because some of the proposed testing scenarios employ a moving stimulus vehicle as well as a moving ADB vehicle (at speeds of up to 70 mph for both), the proposal would require a faster reaction time from ADB systems (and, as discussed earlier in Section VIII.b.iii, we tentatively decided not to include a reaction time allowance). Third, the proposed test scenarios include curves. SAE J3069 specifies a straight track and accounts for curves by specifying test fixtures up to two lanes to either side of the ADB test vehicle, so that "in a straight-line encounter, an ADB must continuously track the angular location of an opposing vehicle as that angular position becomes progressively further from the center of the camera's field of view with decreasing distance to the opposing vehicle." We tentatively believe it is important to test on curves because the safety effect of glare could be magnified when a vehicle is travelling at speed on a curve. In addition, the Agency's testing revealed that existing ADB systems may not always appropriately shade oncoming vehicles in curves; we believe it is important to include this scenario to ensure that ADB systems operate safely. We seek comments on these differences, including the safety impact of adopting the proposed test versus the SAE standard.

The Agency has tentatively concluded that these proposed test scenarios are objective and strike a reasonable balance between safety and practicability. The proposal includes realistic vehicle speeds, interactions, and road geometries. We believe it is not unreasonable to expect an ADB system to avoid glaring other motorists in these scenarios. We considered, but are not proposing, a broader set of scenarios and/or test parameter values (*e.g.*, additional radii of curvature, testing with multiple stimulus vehicles). This would have allowed the Agency to test with a greater degree of realism. However, a broader range of test scenarios may have led to less confidence in the repeatability of test results. In any case, we tentatively believe that the proposed set of scenarios is sufficient to provide a minimum level of safety; they include a broad range of actual vehicles on a test track traveling at (up to) highway speeds, on curved and straight road segments.

At the same time, we tentatively conclude that the scenarios we are proposing are practicable, although some scenarios might be challenging for some ADB systems. The Agency's testing indicated that the ADB systems we tested generally performed well on straight roads, for oncoming and preceding glare.[103] However, we did see some exceedances for a stationary stimulus vehicle in this scenario, suggesting a stationary oncoming vehicle may be more difficult for ADB systems we tested to handle.[104] ADB systems also generally performed well in shading preceding vehicles on curves. We observed that ADB systems we tested had difficulties staying within the glare limits on curves for oncoming vehicles.[105] It may be that on a curve the stimulus vehicle coincides with larger horizontal angles of the beam pattern where the intensity of light may be higher. Accordingly, it may be possible to design headlamps so the intensity of light at these wider angles is brought down to the proposed glare limits.

Additionally, it might also be the case that ADB systems experiencing test failures are not able to view, classify, and adapt to an oncoming vehicle through a curve in a realistic high-speed interaction. The Agency's research included testing on various curves, but of particular applicability to this proposal are tests conducted on a curve with a radius of 764 ft. at 62 mph. As shown in the research report graphs,[106] the ADB systems we tested were unable to react fast enough to avoid providing glare well above the same vehicles' lower beam. As part of this proposal, the Agency considered the real-world significance of this situation and recognized 62 mph is unusually fast for this radius of curvature. Accordingly, the Agency is proposing a lower speed (40–45 mph), which more adequately reflects the typical speed most drivers would approach this type of curve.

We found that some vehicles performed well in all passing maneuver scenarios, while other vehicles did not perform as well in certain passing

[103] ADB Test Report, p. 172.

[104] *Id.* at p. 102.

[105] *Id.* at p. 173.

[106] *Id.* at p. 192 (Fig. 84).

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scenarios (for example, the Audi produced high levels of glare in straight and right curve passing maneuvers).[107] We found that the ADB systems generally performed well with respect to oncoming motorcycles, but produced excessive glare in a scenario involving a preceding motorcycle.[108]

There are some common scenarios we considered but are not proposing to test because we recognize that current ADB systems could not reasonably be expected to perform well, or they might be difficult to specify to ensure repeatable results. For example, the proposal does not include testing ADB performance when approaching a vehicle at an intersection oriented perpendicular to the ADB vehicle's direction of travel. [109] We have tentatively decided not to include this scenario because NHTSA's testing indicated that existing ADB systems would have a difficult time complying with this, and we believe the magnitude and effect of glare in this situation would be relatively minimal because the vehicle illuminated by the ADB system would be stopped or preparing for a stop. Examples of other scenarios not proposed are testing with multiple stimulus vehicles; performing more complicated vehicle maneuvers; and performing on dips or hills (this is discussed below in Section VIII.b.iv.5).

We seek comment on all aspects of the proposed test scenarios. Is 70 mph an appropriate maximum speed? Will it be practicable for manufacturers to run compliance tests based on these proposed test procedures, if they so choose to do this as a basis for their certification?

2. Lane Width

We also propose that any test track or road we use have a lane width from 10 feet to 12 feet. The Federal Highway Administration classifies roads by functional types: Arterials, collectors, and local roads.[110] Design speeds on arterials and collectors range from about 20 mph on up; [111] because these roads generally provide enhanced mobility, it is reasonable to believe speeds are generally higher than this. Design speeds for local roads are generally lower, ranging from about 20 to 30 mph.[112] ADB systems are typically designed to activate at speeds above typical city driving speeds; activation speeds of vehicles tested by NHTSA ranged from 19 to 43 mph. Thus, ADB systems could conceivably be used on all types of roads, although ADB would be less likely to be used on local roads (at least in urban settings).

While 12-foot lanes are standard on arterials such as interstates and expressways, a sizeable proportion of collectors and local roads (as well as other types of arterials) have narrower lanes. Arterials and collectors together make up approximately one-third of all roadways.[113] About 55% of arterials and collectors have 12-ft. lanes.[114] However, about 33% have 10 or 11 ft. lanes.[115] Local roads account for approximately two-thirds of all roadways.[116] Local road widths generally range from 8 to 10 ft.[117] NHTSA's testing was conducted on several different track configurations with lane widths of 9, 10.5, and 12 feet.

We tentatively believe using lanes with widths from 10 feet to 12 feet would be adequate to cover a sufficient range of road widths the ADB would encounter in the real world. This would allow lanes narrower than specified in SAE J3069, which tests on a 12 foot lane, but is consistent with the Insurance Institute for Highway Safety headlight testing protocol, which uses a lane of 10.8 ft.[118] We believe that using the proposed range better reflects the range of lane widths on roads where ADB would likely be used. The less the lateral separation between the ADB-equipped vehicle and either oncoming or preceding vehicles, the greater the glare risk (although differences in lateral separation of only a couple of feet may not be expected to have a material effect on the amount of glare). At the same time, we do not believe it is necessary to use lanes narrower than 10 feet because at the speeds at which ADB is operational, lane widths would not, typically, appear to be under 10 feet. Narrower lanes might also affect the safety of running the test.

3. Number of Lanes, Median, and Traffic Barriers

We propose to test using two adjacent lanes. The effects of glare decrease as the angle between the glare source and the observer increases. Accordingly, the glare risk is most acute on 2-lane roads.[119] A properly-functioning ADB system should be capable of detecting and not glaring vehicles in non-adjacent lanes. However, we tentatively conclude that if a system detects and avoids glaring in same lane and adjacent lane scenarios, additional lanes will likely not affect test outcomes. A median of 0 to 20 feet may separate the two lanes. The median may include a barrier wall, but the barrier must not be taller than 12 inches less than the mounting height of the stimulus vehicle's headlamps.

4. Road Surface

We propose that the road surface be of any material (*e.g.*, concrete, asphalt, etc.) but shall not be bright white. Avoiding a bright white road surface will assist in limiting the effects of ambient and reflected light.

We follow SAE J3069 and specify that the road surface have an International Roughness Index (IRI) of less than 1.5 m/km.[120] The IRI is an internationally recognized measure of road surface roughness; the lower the IRI value, the smoother the road, with an IRI of 0 corresponding to a perfectly smooth road. A smooth road is important for the proposed test because an uneven road surface can cause the ADB-equipped vehicle to change pitch, which can lead to anomalies or spikes in the illuminance measurements.[121] This could lead an otherwise compliant headlight beam to exceed the glare

[107] *Id.* at p. 173.

[108] *Id.* at p. 173.

[109] ADB Test Report, p. 110.

[110] *See* Highway Functional Classification Concepts, Criteria, and Procedures, Federal Highway Administration (*hereinafter* "HFCC"), *available at https://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/fcauab.pdf.* Arterials (such as interstates and expressways) generally handle longer trips; collector roads collect and disperse traffic between arterials and the lower level roads; and local roads provide access function to homes, businesses, and other locations. Arterials provide relatively high levels of mobility and less access, whereas the opposite is true for local roads, and connectors fall in between. Higher levels of mobility are generally associated with higher speeds.

[111] AASHTO Green Book, p. 6–2 (rural collectors); AASHTO Green Book, p. 6–11 (urban collectors); HFCC p. 43 (arterials); AASHTO Green Book, p. 7–2 (rural arterial); AASHTO Green Book, p. 7–27 (urban arterial). Various speed ratings can be used to describe a road—*e.g.*, operating speed, running speed, speed limit, and design speed. The discussion here focuses on design speed, which is "a selected speed used to determine the various geometric design features of the roadway . . . [and] should be a high-percentile value in this speed distribution curve[.]" AASHTO Green Book, pp. 2–54 to 2–55.

[112] AASHTO Green Book, p. 5–2 (rural local); p. 5–11 (urban local).

[113] Highway Statistics 2014. Department of Transportation, Federal Highway Administration, *available at https://www.fhwa.dot.gov/policyinformation/statistics.cfm,* Table HM–220 (miles); Table HM–260 (lane-miles). All citations to tables are from this edition of Highway Statistics. We consider arterials and collectors together and separately from local roads because of the way the data is reported. If the analysis were based on vehicle miles traveled, the result would likely be similar. *See* HFCC pp. 22–23.

[114] Calculated from Table HM–53.

[115] Calculated from Table HM–53.

[116] Calculated from Table HM–220.

[117] HFCC, p. 23.

[118] IIHS Headlight Test and Rating Protocol (November 2016), p. 5 (3.3 m).

[119] 2007 Report to Congress, pp. iv–v.

[120] SAE J3069 7.1.

[121] *See* John D. Bullough, Nicholas P. Skinner & Timothy T. Plummer. 2016. Assessment of Adaptive Driving Beam Photometric Performance. SAE Technical Paper 2016–01–1408, doi:10.4271/2016–01–1408, p. 3.

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limits. (The photometry requirements and the lower beam pattern are based on a nominally level vehicle headlighting system; an increase in vehicle pitch shifts the beam pattern up, which could glare oncoming or preceding vehicles.)

An IRI value of 1.5 corresponds to a newly paved road without any potholes, pitting, or bumps.[122] The Federal Highway Administration classifies roads with an IRI less than 1.5 as "Good," those with an IRI from 1.5 to 2.7 as "Fair", and those with an IRI greater than 2.7 as "Poor."[123] Approximately 37% of pavement miles on Federal-aid highways were rated as having "Good" ride quality in 2012.[124] This suggests the proposed IRI value is realistically achievable on a test track because it is realistically achievable on the much less-controlled environments of actual roads. The vehicle test facility at which NHTSA conducted its testing regularly measures the IRI of at least some of its track surfaces and has generally found them to have IRI values within the proposed range.

5. Grade of Test Road

We propose to use a road approximating a uniform, level road, with a longitudinal grade (slope) not exceeding 2%. We are not proposing to test on sloped (dipped or hilly) roads. Even headlights with compliant lower beam photometry can glare oncoming or preceding vehicles on sloped roads because the hill geometry may place that vehicle in the brighter portion of the lower beam pattern. NHTSA's testing was consistent with this, showing ADB headlights and FMVSS-compliant lower beams glared oncoming and preceding vehicles on roads with dips.[125] It would be neither practical nor consistent with the approach of this rulemaking (extending the existing lower beam glare requirements to ADB systems) to require this performance of ADB systems.

c. Repeatability

The Agency has collected extensive testing data and is docketing this data. The Agency has done several different analyses of this data to assess the repeatability of the proposed compliance test.

One method is pooled standard deviation.[126] Same-direction and oncoming curve scenarios tended to have the smallest maximum pooled standard deviation values across all four distance ranges. Also, maneuvers involving the stimulus vehicle (also referred to here as the "DAS" vehicle) being stationary tended to have smaller pooled standard deviations. This was especially true for curve maneuver scenarios in which the DAS vehicle was stationary, likely because of the short period of time in which the test vehicle's heading was in the direction of the stimulus vehicle.

Another method is visual analysis of data plots from each scenario the Agency tested.[127] These plots demonstrate each run collected data such that the overall shape of the curve (illuminance as a function of distance) is consistent across each test repetition. In most cases, the deviation between data collection runs is small, and for those where larger differences occur, differences can be reasonably attributable to faulty sensors or lack of rigorous equipment configurations for the particular situation such as the motorcycle photometers were not mounted on the motorcycle itself but were on a car positioned nearby (these data are useful for other findings but not for evaluating repeatability). Finally, these plots allow us to evaluate the extent to which the variability within the test itself can be reasonably accounted for in the basic design of the ADB headlighting system. That is to say, this method allows the Agency to evaluate the magnitude of noise within test results as compared to proposed limits. The method of visual analysis further supports the Agency's tentative conclusion that the proposed test provides manufacturers with adequate notice as to the results of any compliance testing the Agency may conduct on its product. The Agency seeks comment on this analysis and these tentative conclusions.

The Agency further examined its research results to understand the validity of the tests. This examination is part of the basis for which the Agency has confidence the proposed tests can generate accurate results and adequately distinguish between an ADB system that is likely to expose others to excessive glare and an ADB system that will not. Table 5 shows results of NHTSA measurements in the baseline (static) condition in which we would expect the photometry to be the least influenced by uncontrollable factors. This is the most basic progression beyond testing headlamps outside of the typical photometric lab used in most regulatory test procedures. As a general observation, we note the mean of each static measurement is below the proposed glare limits for each distance for a lower beam headlighting system. We also note the upper beam illumination at 120 meters is higher than one would expect for an FMVSS headlighting system; however, we also note all four of these vehicles were originally designed to the UNECE standard, which allows for considerably higher intensity upper beam headlamps. Consistent with the information provided to us by the vehicle manufacturer, the Mercedes-Benz and Audi vehicles' upper beam headlamps appear to be within the FMVSS upper beam maximum limit while the other two vehicles are likely outside of this limit. While we were unable to do a standard laboratory photometry test on these headlamps, these data provide confidence NHTSA measurements are reasonable.

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[122] Michael W. Sayers & Steven M. Karamihas. 1998. The Little Book of Profiling, Basic Information About Measuring and Interpreting Road Profiles. University of Michigan. p. 48.

[123] 2015 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance, Report to Congress, Department of Transportation, Federal Highway Administration, Federal Transit Administration, p. 3–4, *available at https://www.fhwa.dot.gov/policy/2015cpr/pdfs.cfm* (last accessed Sept. 26, 2018).

[124] *Id.* p. 3–3. Many states appear to use similar categorization. The Virginia DOT considers interstates and primary roads with an IRI less than .95 to be "Excellent," and those with an IRI from .95 to 1.6 to be "Good." Approximately one third of interstates in Virginia were rated Excellent, and half were rated Good. Virginia Department of Transportation. State of the Pavement 2016. pp. IV–V, *available at http://www.virginiadot.org/info/resources/State_of_the_Pavement_2016.pdf* (last accessed Sept. 26, 2018).

[125] ADB Test Report, pp. 102, 108, 114.

[126] ADB Test Report, pp. 138–145. The pooled variance is a weighted mean of variances of individual groups, groups in this case being the six different test vehicle/stimulus vehicle combinations. This ignores differences in mean values for different groups and compares only the variability within the groups. The pooed standard deviation is the square root of this. Standard deviations calculated by comparing all values to the overall mean are larger because that calculation includes variability between the groups. The pooled standard deviation method of measuring repeatability measures how well values from one repetition to another of the same maneuver compare to each other for any test vehicle even if the means for the different test vehicles are different.

[127] ADB Test Report, pp. 147–162.

Table 5

Baseline Measured Illuminance Values by Headlighting System Mode and Ambient Conditions (Receptor Head 1), Small DAS											
DAS Vehicle Heading	Distance	Vehicle Headlighting System Setting		Audi A8 (n=3)		BMW X5 (n=3)		Lexus LS460 (n=2)		Mercedes-Benz E350 (n=3)	
		ADB	DAS	Average (lux)	SD	Average (lux)	SD	Average (lux)	SD	Average (lux)	SD
NW	N/A	OFF (ambient)	OFF (ambient)	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.01
	30 m (98 ft.)	OFF	LOWER	0.47	0.03	0.52	0.03	0.49	0.02	0.46	0.01
		LOWER	LOWER	1.41	0.57	2.02	0.06	1.59	0.10	1.74	0.05
		LOWER	OFF	1.27	0.04	1.51	0.10	1.09	0.08	1.27	0.05
		UPPER	OFF	31.48*	0.05	31.48*	0.02	31.48*	0.07	31.50*	0.05
NW	60 m (197 ft.)	LOWER	LOWER	0.95	0.00	0.88	0.04	0.80	0.02	0.97	0.03
		LOWER	OFF	0.47	0.02	0.37	0.03	0.30	0.02	0.48	0.05
		UPPER	OFF	30.77*	1.15	31.49*	0.01	31.47*	0.01	22.95	5.50
NW	120 m (394 ft.)	LOWER	LOWER	0.71	0.09	0.60	0.03	0.56	0.01	0.64	0.05
		LOWER	OFF	0.26	0.09	0.10	0.01	0.10	0.03	0.15	0.01
		UPPER	OFF	10.87	0.48	14.83	0.28	16.92	2.75	6.67	1.15
SE	N/A	OFF (ambient)	OFF (ambient)	0.03	0.03	0.12	0.07	0.07	0.07	0.02	0.01
	30 m (98 ft.)	OFF	LOWER	0.53	0.03	0.72	0.10	0.59	0.07	0.52	0.03
		LOWER	LOWER	1.73	0.08	1.95	0.22	1.68	0.08	1.83	0.03
		LOWER	OFF	1.23	0.09	1.41	0.18	1.15	0.08	1.33	0.03
		UPPER	OFF	31.48*	0.07	31.46*	0.00	31.48*	0.01	31.50*	0.04
SE	60 m (197 ft.)	LOWER	LOWER	0.96	0.01	1.00	0.13	0.90	0.07	0.98	0.01
		LOWER	OFF	0.41	0.10	0.47	0.08	0.38	0.06	0.48	0.01
		UPPER	OFF	28.69	0.56	31.46*	0.00	29.76	1.91	21.20	3.45
SE	120 m (394 ft.)	LOWER	LOWER	0.75	0.03	0.74	0.12	0.67	0.06	0.77	0.10
		LOWER	OFF	0.23	0.05	0.21	0.08	0.16	0.07	0.23	0.03
		UPPER	OFF	10.73	0.31	13.96	1.44	16.91	2.05	6.85	1.05

***Note: Trials averaged to obtain these noted values include at least one instance of measurement clipping because of raw illuminance level data exceeding the measurement range of the illuminance meter.**

Table 6

			Average Maximum Illuminance by Receptor Head 1 Static and Dynamic – Oncoming, Straight, Curve, Adjacent Lane Maneuvers with Small DAS Vehicle											
			Audi			BMW			Lexus			Mercedes-Benz		
			Lower Beam			Lower Beam			Lower Beam			Lower Beam		
Maneuver Scenario	Range (m)	Glare Limit (lux)	Dynamic (n=3)	Baseline (n=3)	% Diff	Dynamic (n=3)	Baseline (n=3)	% Diff	Dynamic (n=3)	Baseline (n=3)	% Diff	Dynamic (n=3)	Baseline (n=3)	% Diff
Straight, DAS 0 mph, ADB 62 mph	15-29.9	3.109	1.63	Not Reported		2.58	Not Reported		1.67	Not Reported		2.27	Not Reported	
	30-59.9	1.776	0.74	1.27	-42%	2.01	1.51	33%	0.94	1.09	-14%	1.05	1.27	-17%
	60-119.9	0.634	0.35	0.47	-26%	0.29	0.37	-22%	0.33	0.30	10%	0.36	0.48	-25%
	120-239.9	0.281	0.18	0.26	-31%	0.03	0.10	-70%	0.14	0.10	40%	0.15	0.15	0%
Straight, DAS 62 mph, ADB 62 mph	15-29.9	3.109	1.50	Not Reported		2.98	Not Reported		1.73	Not Reported		2.27	Not Reported	
	30-59.9	1.776	0.80	1.27	-37%	1.60	1.51	6%	1.06	1.09	-3%	0.98	1.27	-23%
	60-119.9	0.634	0.45	0.47	-4%	0.29	0.37	-22%	0.34	0.30	13%	0.36	0.48	-25%
	120-239.9	0.281	0.23	0.26	-12%	0.03	0.10	-70%	0.15	0.10	50%	0.15	0.15	0%
ADB curves Left, DAS	15-29.9	3.109	1.90	Not Reported		2.00	Not Reported		2.19	Not Reported		2.61	Not Reported	
	30-59.9	1.776	1.07	1.27	-16%	0.86	1.51	-43%	1.23	1.09	13%	1.27	1.27	0%

Table 6 includes results of the lower beam headlamp illumination measurements when taken through NHTSA dynamic tests including oncoming scenarios, on a curve (right and left), and on a straightaway with the

0 mph, ADB 62 mph	60-119.9	0.634	0.55	0.47	17%	0.18	0.37	-51%	0.58	0.30	93%	0.62	0.48	29%
	120-239.9	0.281	0.46	0.26	77%	0.03	0.10	-70%	0.44	0.10	340%	0.47	0.15	213%
ADB curves Left, DAS 62 mph, ADB 62 mph	15-29.9	3.109	1.93	Not Reported		1.92	Not Reported		1.94	Not Reported		2.54	Not Reported	
	30-59.9	1.776	1.08	1.27	-15%	0.86	1.51	-43%	1.16	1.09	6%	1.26	1.27	-1%
	60-119.9	0.634	0.57	0.47	21%	0.21	0.37	-43%	0.59	0.30	97%	0.64	0.48	33%
	120-239.9	0.281	0.47	0.26	81%	0.07	0.10	-30%	0.47	0.10	370%	0.49	0.15	227%
ADB curves Right, DAS 0 mph, ADB 62 mph	15-29.9	3.109	2.28	Not Reported		1.63	Not Reported		1.75	Not Reported		2.38	Not Reported	
	30-59.9	1.776	1.63	1.27	28%	0.78	1.51	-48%	1.21	1.09	11%	1.35	1.27	6%
	60-119.9	0.634	0.78	0.47	66%	0.22	0.37	-41%	0.57	0.30	90%	0.77	0.48	60%
	120-239.9	0.281	0.57	0.26	119%	0.07	0.10	-30%	0.40	0.10	300%	0.58	0.15	287%
ADB curves Right, DAS 62 mph, ADB 62 mph	15-29.9	3.109	2.54	Not Reported		1.79	Not Reported		1.73	Not Reported		2.44	Not Reported	
	30-59.9	1.776	1.53	1.27	20%	0.73	1.51	-52%	1.14	1.09	5%	1.30	1.27	2%
	60-119.9	0.634	0.71	0.47	51%	0.16	0.37	-57%	0.54	0.30	80%	0.70	0.48	46%
	120-239.9	0.281	0.54	0.26	108%	0.00	0.10	-100%	0.37	0.10	270%	0.52	0.15	247%

stimulus vehicle moving and stationary. For purposes of examining the validity of the proposed test, the Agency first considered results of lower beam testing only to remove potential variabilities in test results from the performance of ADB systems. The most closely comparable measurements are the baseline and the straight maneuver as the general orientation for these situations place the vehicle mounted photometers in similar locations for each test. We note measurements for dynamic situations differ from the static in positive and negative ways meaning sometimes the dynamic test produces a higher illumination reading, while in others, it produces a lower illumination measurement as compared to the baseline measurement. Also of significant note, for straight situations, the far distance (120–239.9 m range) produced generally higher percentage differences between the baseline and the dynamic situation. This may be expected as stray light will have a larger percentage contribution considering the smaller base value. Additionally, vehicle pitch variation as measured in angles would have a larger contribution if the lower beam headlamp cutoff were to approach photometers. This second possibility seems the less likely of the two as dynamic measurements were not consistently higher than the baseline measurement for that range and orientation but similar to the other measurement ranges. Sometimes the baseline measurement was higher, and sometimes the dynamic measurements were higher.

Curve situations (both left and right) demonstrated a greater difference between baseline and dynamic tests, particularly at the far distance range. Importantly, the difference did not seem to be compounded with the stimulus vehicle moving as opposed to stationary. One possible explanation for the difference between baseline results and curve results is the orientation of the two vehicles is different. While for the straight situations photometers are in a similar place within the test vehicles' headlamp beam pattern, for the curve situation the vehicle orientation moves the stimulus vehicle (and mounted photometers) out toward larger horizontal angles of the beam pattern where the intensity of light seems to be higher in three of these test vehicles. The BMW consistently did not demonstrate this difference, leading the Agency to believe the test is measuring true differences in vehicles' beam patterns even at large angles in the curve situation. Additionally, the right curve with and without the stimulus vehicle moving recorded similar results as the left curve with and without the stimulus vehicle moving for each of the vehicles tested. As such, the Agency tentatively concludes the difference between baseline and curve situations do not demonstrate variability within the test procedure itself but are caused by variations in beam patterns of test vehicles. Not the topic of this section, however, this examination leads the Agency to tentatively conclude situations in which these far distance curves produced glare beyond tentative limits can be designed out of headlamps.

Considering the confidence established in the Agency's ability to measure lower beam performance in an outdoor test on-vehicle, the Agency next evaluated the performance of the ADB system and evaluated the tests' ability to measure ADB headlighting systems in a dynamic way. First, we compared oncoming straight results between lower beam and ADB as shown in Table 7.

Table 7

Maneuver Scenario	Range (m)	Glare Limit (lux)	Audi (n=3)			BMW (n=3)			Lexus (n=3)			Mercedes-Benz (n=3)		
			Lower Beam Illuminance (lux)	ADB Illuminance (lux)	Quotient (ADB / Lower Beam)	Lower Beam Illuminance (lux)	ADB Illuminance (lux)	Quotient (ADB / Lower Beam)	Lower Beam Illuminance (lux)	ADB Illuminance (lux)	Quotient (ADB / Lower Beam)	Lower Beam Illuminance (lux)	ADB Illuminance (lux)	Quotient (ADB / Lower Beam)
Straight, DAS 0 mph, ADB 62 mph	15-29.9	3.109	1.63	2.00	1.23	2.58	3.23	1.26	1.67	1.50	0.90	2.27	2.50	1.10
	30-59.9	1.776	0.74	0.78	1.06	2.01	1.85	0.92	0.94	0.99	1.05	1.05	1.14	1.08
	60-119.9	0.634	0.35	0.32	0.90	0.29	0.37	1.28	0.33	0.44	1.34	0.36	0.41	1.16
	120-239.9	0.281	0.18	0.14	0.80	0.03	0.05	1.99	0.14	0.37	2.70	0.15	0.16	1.05
Straight, DAS 62 mph, ADB 62 mph	15-29.9	3.109	1.50	2.89	1.93	2.98	2.99	1.01	1.73	1.49	0.86	2.27	2.34	1.03
	30-59.9	1.776	0.80	0.81	1.01	1.60	1.95	1.22	1.06	0.94	0.89	0.98	1.04	1.07
	60-119.9	0.634	0.45	0.42	0.93	0.29	0.38	1.33	0.34	0.35	1.04	0.36	0.39	1.09
	120-239.9	0.281	0.23	0.22	0.98	0.03	0.08	2.65	0.15	0.22	1.46	0.15	0.14	0.93

We expected the straight scenario would pose the least difficult situation for the performance of the ADB system itself and allow the Agency to evaluate the test. As such, we expected ADB results to be similar to lower beam results for the same maneuver. Table 7 compares the maximum illumination value recorded for lower beam headlamps as compared to ADB systems and presents the quotient of the ADB divided by the lower beam. Ideally, we would expect the quotient to equal 1. A value less than 1 identifies results in which the ADB is dimmer than the lower beam, while values greater than 1 identify results in which the ADB is brighter than the lower beam. In general, the results indicate the quotient is close to 1 with some exceptions. The far distance range produced a quotient 2.65 on the BMW, meaning ADB system results for that range are more than twice as bright as lower beam results. This result is, however, a ratio of small numbers, namely 0.08 divided by 0.03. To provide context around these small numbers, the research threshold value for that range is 0.281 (0.3 as proposed today), much greater than recorded results for either headlighting system. The far distance range for the Lexus vehicle produced a ratio of 2.7 meaning ADB results are approaching three times as bright as the lower beam. Unlike results for the BMW, the Lexus measurements are not particularly small numbers. In fact, the ADB measurement for that test was 0.37 lux, which is above the research threshold for the far distance range. Interestingly, the Mercedes-Benz ADB results were within 16% of lower beam results for all ranges corresponding to the straight maneuver. This leads the Agency to the tentative conclusion favorable ratios between the lower beam and ADB systems are technically possible, and the test procedure is useful in discerning the performance of the ADB system in the straight maneuver.

The Agency research also included the evaluation of more complex maneuvers and scenarios to evaluate the ADB performance in situations that are more likely to challenge the ADB system's functionality. Table 8 presents results of the ADB system's performance on the curve maneuver.

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Table 8

Curve Scenarios

			Audi (n=3)			BMW (n=3)			Lexus (n=3)			Mercedes-Benz (n=3)		
Maneuver Scenario	Range (m)	Glare Limit (lux)	Lower Beam Illuminance (lux)	ADB Illuminance (lux)	Quotient (ADB / Lower Beam)	Lower Beam Illuminance (lux)	ADB Illuminance (lux)	Quotient (ADB / Lower Beam)	Lower Beam Illuminance (lux)	ADB Illuminance (lux)	Quotient (ADB / Lower Beam)	Lower Beam Illuminance (lux)	ADB Illuminance (lux)	Quotient (ADB / Lower Beam)
ADB curves Left, DAS 0 mph, ADB 62 mph	15-29.9	3.109	1.90	2.05	1.08	2.00	2.22	1.11	2.19	2.24	1.02	2.61	2.77	1.06
	30-59.9	1.776	1.07	1.22	1.14	0.86	1.00	1.17	1.23	1.32	1.07	1.27	1.42	1.11
	60-119.9	0.634	0.55	1.61	2.92	0.18	0.38	2.14	0.58	0.81	1.41	0.62	1.06	1.71
	120-239.9	0.281	0.46	0.50	1.09	0.03	0.07	1.96	0.44	0.49	1.10	0.47	0.59	1.27
ADB curves Left, DAS 62 mph, ADB 62 mph	15-29.9	3.109	1.93	2.08	1.08	1.92	2.11	1.10	1.94	1.88	0.97	2.54	2.77	1.09
	30-59.9	1.776	1.08	1.22	1.13	0.86	0.92	1.07	1.16	1.30	1.12	1.26	1.40	1.11
	60-119.9	0.634	0.57	1.99	3.49	0.21	0.79	3.76	0.59	1.92	3.23	0.64	1.60	2.49
	120-239.9	0.281	0.47	0.50	1.07	0.07	0.11	1.48	0.47	0.51	1.07	0.49	0.60	1.23
ADB curves Right, DAS 0 mph, ADB 62 mph	15-29.9	3.109	2.28	2.59	1.14	1.63	1.60	0.98	1.75	2.14	1.22	2.38	2.45	1.03
	30-59.9	1.776	1.63	1.61	0.98	0.78	0.77	0.98	1.21	1.21	0.99	1.35	1.39	1.03
	60-119.9	0.634	0.78	2.95	3.77	0.22	1.24	5.58	0.57	1.64	2.87	0.77	1.14	1.49
	120-	0.281	0.57	0.65	1.15	0.07	0.14	1.98	0.40	0.42	1.05	0.58	0.89	1.53

	239.9													
ADB curves Right DAS 62 mph, ADB 62 mph	15-29.9	3.109	2.54	2.64	1.04	1.79	1.78	0.99	1.73	2.36	1.36	2.44	2.74	1.12
	30-59.9	1.776	1.53	1.95	1.27	0.73	0.75	1.03	1.14	11.19	9.80	1.30	1.46	1.12
	60-119.9	0.634	0.71	3.23	4.53	0.16	2.33	14.37	0.54	4.28	7.93	0.70	1.54	2.21
	120-239.9	0.281	0.34	0.61	1.12	0.08	0.16	275.97	0.37	0.40	1.09	0.52	0.84	1.61

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As discussed previously, the lower beam exceeded research thresholds for the long range for all vehicles except the BMW. Beyond this, several ADB performance aspects were observed in this test. Again, building on the lower beam performance, the ADB performance was evaluated as a quotient of the maximum illumination as compared to the lower beam for each distance range. Audi results showed high quotients for each of the curve tests for the 60–119.9 m range. Not only is the quotient high, the maximum illumination for that range was reported as 1.61, 1.99, 2.95, and 3.23 lux as presented in the table above. To put these values in perspective, the research threshold for that range is 0.634 lux. While the lower beam, in some cases, exceeded this threshold, the maximum exceedance for the lower beam was a measurement of 0.78 over the threshold by just 23% on the Audi. Based on the confidence in the Agency's test, established in the previous discussion, the Agency tentatively concludes differences shown on curves are true differences in the ADB performance and not variability in the test itself. To further establish this tentative conclusion, the Agency looked at details of the test and plotted the illuminance as a function of distance as shown below. Results for the oncoming curve-left test show the passenger car stimulus vehicle and the SUV stimulus vehicle where both the stimulus vehicle and the ADB vehicles are moving at 62 mph.

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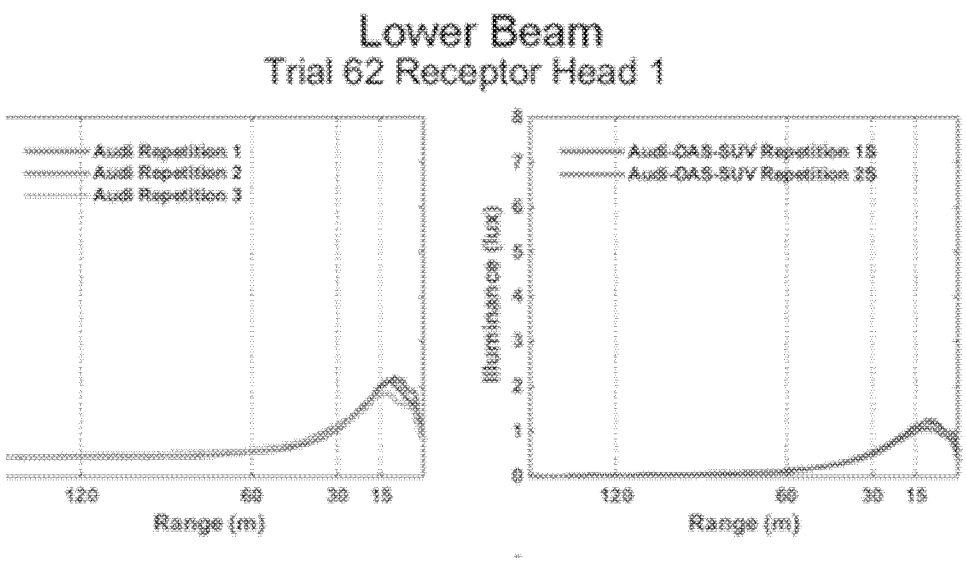


Figure 2

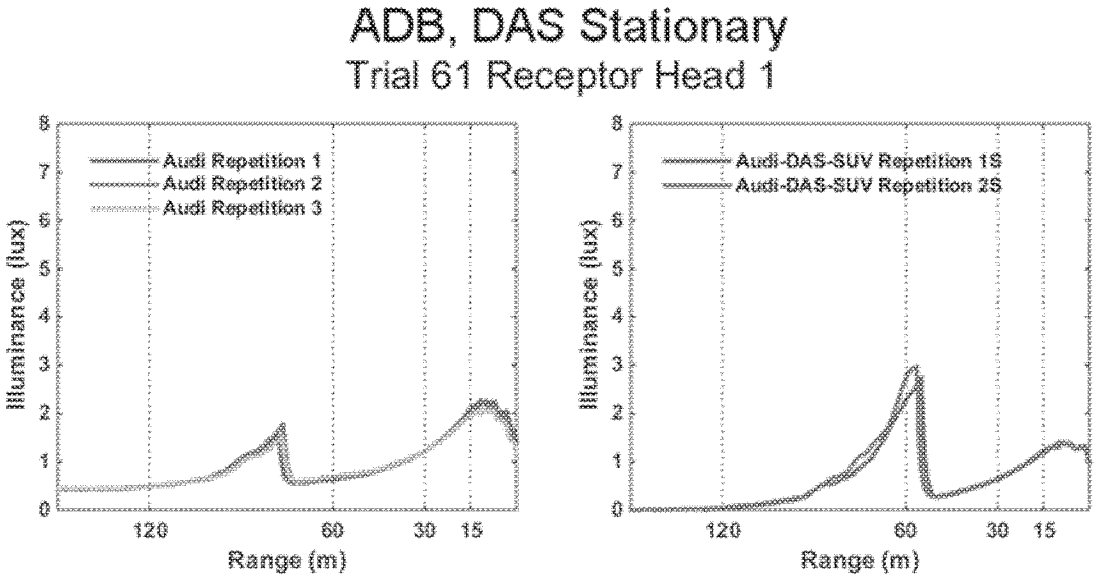


Figure 3

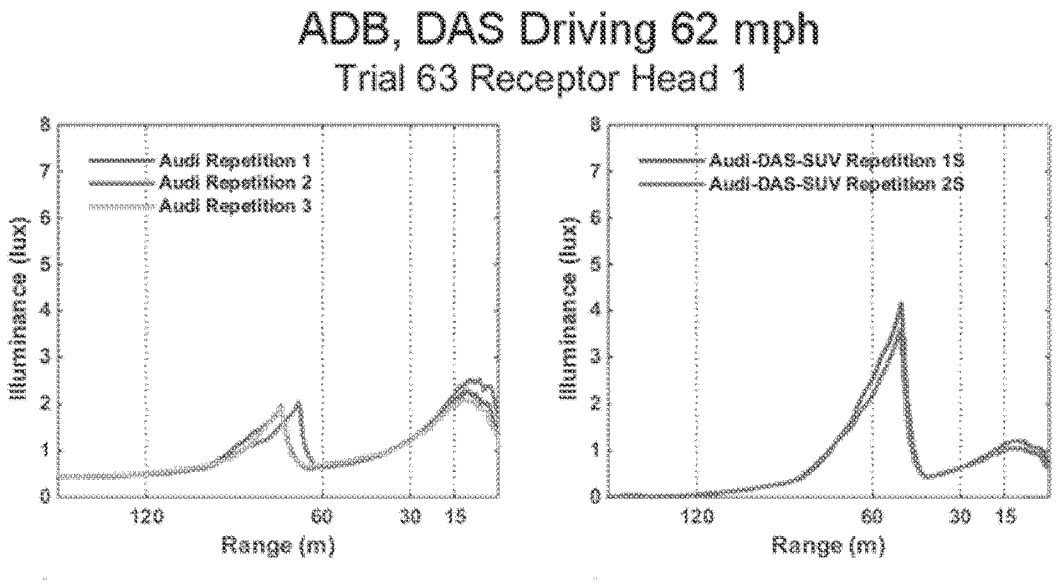


Figure 4

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By comparing the plots, we can see the ADB system is providing a full upper beam (or at least not shading the stimulus vehicle) until suddenly recognizing and dramatically lowering the glare (at round 70 m for the moving passenger car stimulus vehicle and 50 m for the moving SUV stimulus vehicle). The sudden lowering of the illuminance appears to happen sooner for the two stationary stimulus vehicles. The Agency tentatively considers this outcome a byproduct of the ADB system's lack of ability to view, classify, and adapt to an oncoming vehicle through a curve at a realistic but generally high-speed interaction. Further support of this tentative conclusion is that for each of the curve interactions listed above, glare measurements are higher when the stimulus is moving as compared to when it is stopped for the 60–119.9 m range.

Taken together, these results support the Agency's tentative conclusion that the proposed test is repeatable and sufficient in its ability to measure ADB performance using a vehicle-based, dynamic test. Further, the Agency tentatively concludes the variability in the test is small enough that a manufacturer can reasonably anticipate results of any compliance test the Agency would conduct if taken into consideration during design stages of the vehicle and headlighting system.

IX. Certification and Aftermarket

Motor vehicle manufacturers are required to certify that their vehicles comply with all applicable FMVSS.[128] FMVSS No. 108 also applies to replacement equipment (*i.e.*, equipment sold on the aftermarket to replace original equipment installed on the vehicle and certified to FMVSS No. 108 at the time of the first sale to a purchaser other than for resale).[129] Replacement equipment must be designed to conform to meet any applicable requirements and include all functions of the lamp it is designed to replace or capable of replacing.[130] Each replacement lamp which is designed or recommended for particular vehicle models must be designed so that it does not take the vehicle out of compliance with the standard when the individual device is installed on the vehicle.[131] A manufacturer of replacement equipment is responsible for certifying that equipment.[132] It may be the case that only the manufacturer of the original equipment and/or vehicle would be able to make a good faith certification of ADB replacement equipment because requirements are vehicle-level, not equipment level. We seek comment on this.

X. Regulatory Alternatives

The two main regulatory alternatives NHTSA considered were the ECE ADB requirements and SAE J3069. However, as noted earlier, the ECE requirements are not sufficiently objective to be incorporated into an FMVSS. Accordingly, the main regulatory alternative we considered is SAE J3069.

In the preceding sections of this document we discussed in detail specific aspects in which the proposal follows and differs from SAE J3069. In general, there are two major ways in which they differ.

First, the proposal would require a more robust and realistic track test to evaluate glare. This track test is the major element of the proposed rule. It is ultimately based—as is the SAE J3069 track test—on the glare limits developed in NHTSA's Feasibility Study. These glare limits are the foundational element of the track test. The proposal and SAE J3069 differ somewhat in the way the proposed glare limits are specified, but they are largely similar. The proposal differs significantly from SAE J3069, however, in the way that it would test for compliance with these glare limits. SAE J3069 specifies testing on a straight portion of road, and instead of using oncoming or preceding vehicles, uses stationary test fixtures positioned at precisely specified locations adjacent to the test track. The proposed test procedure would permit the Agency to test on curved portions of road (with various radii of curvature) using a broad range of actual FMVSS-certified vehicles as oncoming or preceding vehicles.

Second, the proposal would require additional laboratory-tested equipment-level photometric requirements to regulate both glare and visibility. With

[128] *See, e.g.* 49 U.S.C. 3015.

[129] S3.3 (the standard applies to "[l]amps, reflective devices, and associated equipment for replacement of like equipment on vehicles to which this standard applies.").

[130] S6.7.1.1.

[131] S6.7.1.2.

[132] 49 U.S.C. 30115; Letter from Stephen Wood, Acting Chief Counsel, to George Van Straten, Van Straten Heated Tail Light Co., Inc. (Aug. 11, 1989).

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respect to glare prevention, we propose to require that the part of the ADB beam that is cast near other vehicles must not exceed the current low beam maxima, and the part of an ADB beam that is cast onto unoccupied roadway must not exceed the current upper beam maxima. SAE J3069 requires the former but not the latter. With respect to visibility, we propose that the part of the ADB beam that is cast near other vehicles must comply with the current lower beam minima, and that the part of the ADB beam that is cast onto unoccupied roadway comply with the upper beam minima. SAE J3069 does not have any laboratory-based requirements for the former, and for the latter specifies the low beam minima, not the upper beam minima.

NHTSA has tentatively concluded that the differences between the proposal and SAE J3069 are necessary to ensure the ADB systems meet the dual safety needs of glare prevention and visibility.

NHTSA is particularly concerned about ensuring, to a reasonable degree, that ADB systems do not glare other motorists. The attraction of ADB is that it is able—if designed and functioning properly—to provide enhanced illumination while not glaring other motorists. However, if an ADB system does not perform as intended, it does have the potential to glare other motorists. NHTSA is particularly concerned about this because glare is a negative externality that might not be sufficiently mitigated by market forces alone. Headlamp design involves an inherent tension between forward illumination and glare. A vehicle manufacturer's incentive, absent regulation, might be to provide forward illumination at the expense of glare prevention because the benefits of forward illumination are enjoyed by the vehicle owner, while glare prevention principally benefits other motorists. NHTSA is especially mindful of the many comments and complaints NHTSA has received from the public expressing concerns about glare. The proposed regulation is, therefore, largely focused on glare. This is consistent with the current headlamp regulations, which have included photometry requirements regulating glare since the standard's inception.

NHTSA tentatively believes that the proposed requirements are preferable to SAE J3069. The proposed track test would require that ADB systems be able to negotiate a variety of real-world conditions and not simply be engineered to recognize specified fixtures. We tentatively believe the proposal will lead to ADB systems that prevent glare more effectively, particularly in real-world situations where the other vehicle enters the field of view of the ADB camera from the side and not from a far distance. We also believe that requiring that the part of the ADB beam that is cast near other vehicles must not exceed the current low beam maxima, and the part of the ADB beam that is cast onto unoccupied roadway must not exceed the current upper beam maxima would provide further assurance against glare compared to the less stringent SAE specifications. We tentatively conclude that the regulatory requirements we are proposing would meet the need for vehicle safety and would be sufficient to determine whether an ADB system was functioning properly so as not to glare other motorists.

While the bulk of the proposal is related to glare, and there is reason to believe that manufacturers have an incentive to provide sufficient forward illumination, we also include a very limited set of laboratory tests to ensure a minimum level of visibility. NHTSA tentatively believes that the limited set of proposed laboratory photometric tests not included in SAE J3069 would provide important safety assurances. These laboratory-based requirements only require that the ADB complies with the existing photometry requirements that ensure that minimum levels of illumination are provided. We tentatively believe that if ADB systems did not provide these minimum levels of illumination the driver might not have sufficient visibility.

At the same time, we tentatively believe that more stringent requirements relating to visibility are not necessary. Manufacturers have a market incentive to provide drivers with sufficient illumination. In addition, if an ADB system is malfunctioning in not providing adequate illumination, vehicle owners can file complaints both with the manufacturer and NHTSA. This would make it possible for NHTSA to identify the safety concern, open a defect investigation, and, if the investigation suggests the ADB system is defective, require the OEM to recall and remedy the vehicle. This is largely not the case for glare, because a motorist who is glared by another vehicle is rarely able to identify that vehicle and submit a complaint. Moreover, we believe potential safety benefits of ADB technology justify focusing on what we believe is the most acute regulatory concern (glare), and not including equally stringent requirements and test procedures related to visibility. Based on the Agency's testing, and on the experience with ADB systems in Europe and Asia, it appears that current systems have generally been providing adequate illumination. However, we tentatively believe these minimum requirements are necessary.

A more detailed discussion of the expected likely costs and benefits of the proposal as compared to SAE J3069 is provided below in Section XI, Overview of Costs and Benefits.

As an alternative to the proposed requirements and compliance test procedures, the Agency could more closely follow SAE J3069. We earlier discussed specific ways in which we depart from SAE J3069. We could choose to conform to SAE J3069 with respect to some or all of these test attributes. The major ways the proposal could further conform to SAE J3069 would be by using stationary fixtures, instead of moving vehicles, limiting the array of road geometries we would test with, and not requiring the additional laboratory-based photometric requirements not also included in SAE J3069. We could also incorporate SAE J3069 by reference.

We seek comment on the relative merits of the proposal and SAE J3069 generally, and the advisability of conforming to or departing from SAE J3069 in any of these respects. In particular, with respect to differences between the proposal and SAE J3069: What are the relative merits and drawbacks of each with respect to the statutory criteria of objectivity, practicability, meeting the need for safety, and appropriateness for the type of vehicle? NHTSA is also interested in views regarding differences between the proposal and SAE J3069 in terms of the repeatability of test results. NHTSA is also interested in learning whether there are any other alternatives that should be considered by the Agency.

XI. Overview of Benefits and Costs

NHTSA has considered the qualitative costs and benefits of the proposal. (For the reasons discussed in Section XI, Overview of Benefits and Costs, NHTSA has not quantified the costs and benefits of the proposal.) NHTSA has analyzed the qualitative costs and benefits of the proposal compared to both the current baseline in which ADB systems are not deployed as well as the primary regulatory alternative (SAE J3069). Based on this analysis, NHTSA tentatively concludes that ADB should be permitted and that the proposed requirements and test procedures are the preferred regulatory alternative.

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a. Proposal Compared to Current Baseline in Which ADB is Not Deployed

We have tentatively concluded that the proposal to permit ADB and subject it to requirements and test procedures to ensure that it does not glare other motorists and provides sufficient visibility would have greater net benefits than maintaining the status quo.

We have tentatively determined that the proposal to permit ADB and subject it to requirements and test procedures would lead to greater benefits than maintaining the status quo in which ADB is not deployed. The anticipated benefits are a decrease in fatalities and injuries associated with crashes involving pedestrians, cyclists, animals, and roadside objects due to the improved visibility provided by ADB. The improved visibility is a result of increased upper beam use and an enhanced lower beam. Although it is difficult to estimate these benefits, NHTSA performed a data analysis to explore how driving in better light conditions affects pedestrian and cyclist fatalities. The analysis focused on pedestrian/cyclist fatalities and injuries under various light conditions and explored the correlation between pedestrian/cyclist fatalities and injuries with light conditions, as well as several other risk factors (location, speed limit, alcohol use, and driver distraction). The analysis used data from the Agency's Fatality Analysis Reporting System and the National Automotive Sampling System General Estimate System. These databases contain detailed information on crashes involving fatalities and injuries, respectively, including information on the conditions under which the crashes occurred. This analysis suggests that the size of the target population—pedestrian and cyclist fatalities that occur in darkness—is 15,065 over 11 years or 1,370 per year. This analysis is discussed in more detail in Appendix A. The Agency tentatively concludes this analysis demonstrates that a properly-functioning ADB system could provide significant safety benefits beyond that provided by existing headlighting systems.[133]

The possible disbenefits of this rulemaking would be any increases in glare attributable to ADB. A properly-functioning ADB system would not produce more glare than current headlights because it would accurately recognize and shade oncoming and preceding vehicles. The Agency's research testing of ADB-equipped vehicles leads NHTSA to tentatively conclude that an ADB system that complied with the proposed requirements would not lead to any significant increases in glare. Accordingly, we do not expect any significant disbenefits.[134]

ADB is currently not permitted by FMVSS No. 108, and is therefore not currently available to consumers. The proposed rule, by allowing the introduction of ADB systems, would expand the set of choices open to consumers. ADB systems are optional, and the proposed rule in no way restricts or imposes additional costs or requirements on any existing technologies that consumers are currently able to purchase. Consumers are therefore no worse off under the proposal. Because the proposal expands the set of consumer choices (compared to the status quo), it is an enabling regulation. The estimated cost savings of an enabling regulation would include the full opportunity costs of the previously foregone activities (*i.e.*, the sum of consumer and producer surplus, minus any fixed costs).

Because we expect positive benefits and cost savings from enabling the use of new technologies, we tentatively conclude that the proposal would lead to higher net benefits compared to the status quo. We seek comment on the potential benefits and cost savings of this proposal, including quantitative data that could help estimate their magnitude.

b. Proposal Compared to SAE J3069

NHTSA also compared the proposal to SAE J3069. As discussed below, although the proposal is likely more costly (due to higher compliance testing and equipment costs), these higher costs are likely outweighed by the higher safety-related benefits (and lower glare disbenefits).

The proposal would likely result in greater benefits than the regulatory alternative because the proposed requirements require more illumination (but not at levels that would glare other motorists). Above we broadly estimated the size of the target population. We tentatively believe that the proposed requirements would be more effective—*i.e.*, more likely to lead to a greater reduction in crashes—than SAE J3069 because the proposal would require ADB systems to provide more illumination. Two of the proposed laboratory-based photometric requirements do this. We propose that the part of the ADB beam that is cast near other vehicles must comply with the current lower beam minima, and that the part of the ADB beam that is cast onto unoccupied roadway comply with the upper beam minima. SAE J3069 does not have any laboratory-based requirements for the former, and for the latter specifies the lower beam minima, not the upper beam minima. We believe the proposed requirements would offer meaningful safety assurances. The lower and upper beam minima have been in place for decades. They indicate what have been the longstanding minimum acceptable levels of illumination for adequate visibility. Along with this, they provide an appropriate tradeoff between illumination and glare. While requiring the lower beam minima for the dimmed portion of the ADB beam may not provide much benefit when the ADB system is dimming portions on an oncoming or proceeding vehicle, any activation of the dimmed region due to a false positive (dimming for a lamp post or sign) could have safety implications (because there would not be another vehicle's headlamps to illuminate the road). Because SAE J3069 does not require ADB systems to meet any minima within the dimmed portion of the ADB beam, it could lead to insufficient illumination. On the other hand, it might be possible that the more demanding road test we propose to test for glare could incentivize manufacturers to equip vehicles with ADB systems that provide less illumination (to ensure that they do not fail the glare road test) than they would if we adopt requirements more similar to SAE J3069. However, we tentatively believe the proposed requirements will result in a greater reduction in crashes due to increased illumination.[135]

[133] As discussed in Appendix A, the analysis requires a variety of assumptions and, while partially accounting for some confounding factors (such as alcohol-related crashes), is not able to isolate the effect of darkness on crash risk. (Toyota also estimated the target population, using a different methodology, in its rulemaking petition.) Determining a more specific target population is difficult because of a variety of data limitations (e.g., headlamp state (on-off, upper-lower beam) is not known in many of the pedestrian crashes).

[134] We do recognize, as the ADB Test Report notes, that there are situations in which ADB might not adequately perform, such as at intersections and on dipped segments of roadway. We believe that at intersections the safety concern is lessened because the encountered vehicle is likely stationary. We also note that current headlights, which are unable to actively adapt the beam, can glare other vehicles at intersections and on dipped roads because the roadway geometry becomes such that those vehicles are exposed to relatively bright portions of the beam.

[135] The proposal and the alternative both are most likely to be cost-effective using the DOT's $9.7 million value of a statistical life. However, due to the relatively more stringent performance requirements of the proposal, it would likely accrue more safety benefits than does the alternative.

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The Agency has also tentatively concluded that the proposed requirements would lead to smaller disbenefits in terms of glare than the regulatory alternatives, for two reasons. First, the proposal requires a much more realistic road test to evaluate glare, including actual vehicles and curved portions of the roadway, instead of fixtures simulating vehicles and curves. This would require that ADB systems be able to meet a variety of real world conditions and not simply be engineered to recognize specified fixtures. We tentatively believe this will lead to less glare, particularly in real-world situations where the other vehicle enters the field of view of the ADB camera from the side and not from a far distance (such as situations in which the ADB-equipped vehicle is overtaken or encounters an oncoming vehicle on a small-radius curve). Second, the proposal would require that in the undimmed portion of the ADB beam the current upper beam maxima be met; SAE J3069 does not specify any maxima. The upper beam maxima limit the amount of light projected on objects that are not detected by the ADB system such as cyclists, pedestrians, and houses near the road.

NHTSA tentatively concludes that the proposed rule would likely have higher costs than SAE J3069. This is due to compliance testing costs, and, possibly, to component costs.

We would expect higher costs for compliance testing. The proposed road test for compliance with the proposed glare limits is more complex than the testing required by SAE J3069 because it involves actual test vehicles and more scenarios. The proposal also includes requirements for static photometry testing that are not included in SAE J3069. If a manufacturer concluded that testing was necessary to certify an ADB system, then testing for compliance with the proposal would be more costly than compliance testing for a standard more closely based on SAE J3069.

We do not expect design and development costs to be significantly higher than they would be under SAE J3069. ADB is currently offered as an optional system in Europe, among other markets. We tentatively believe that the European ADB (if modified to produce a U.S.-compliant beam [136]) systems are essentially capable of complying with the proposed requirements. The Agency tested a variety of European vehicles in a road test similar to the one that is proposed today to measure glare. The vehicles passed many of the scenarios we tested, although we observed that the ADB systems had difficulties staying within the glare limits when encountering oncoming vehicles on curves when both vehicles were travelling at approximately 60 mph. In consideration of these test results, the proposal does not include any tests on curves at these higher speeds. (In the proposal, we are proposing that the vehicle's speeds not exceed 45 mph in this scenario.)

However, we do believe that it could be more costly to equip a vehicle with an ADB system that complies with the proposal rather than with the minimum requirements of SAE J3069. For instance, the proposal requires that the undimmed portion of the ADB beam meet the current upper beam minima. The European systems we tested similarly used the upper beam (ECE driving beam) to illuminate regions outside the dimmed portion of the beam. SAE J3069, however, requires only that the lower beam minima be met in this region. Accordingly, an SAE J3069-compliant system could use a lower cost light source. As another example, while the European systems NHTSA tested employed relatively sophisticated LED arrays or shading devices, a system that complied with the minimum requirements of SAE J3069 could employ less sophisticated technology.

NHTSA has tentatively concluded that the likely additional (*i.e.*, as compared to SAE J3069) benefits associated with the proposal exceed the likely additional costs of the proposal. The somewhat greater costs it would require to equip a vehicle with an ADB system that complies with the proposed requirements would likely be outweighed by the greater benefits (and smaller glare disbenefits) that we tentatively believe would be likely to result from the proposal. For instance, a system that saved money on a narrow field of view camera would not provide glare protection on small radius curves in real world driving. Additionally, any cost savings to be gained from a less intense light source used for the undimmed portion of the beam would be negated by the relative increase risk to pedestrian detection.

NHTSA seeks comment on all these issues, in particular the relative costs of compliance with the proposal, SAE J3069, and the ECE requirements (especially specific data and cost estimates), as well as the relative benefits of these alternatives.

[136] Because the headlamp photometry requirements in FMVSS No. 108 differ from ECE-required photometry, in order for an ECE-compliant system to be sold in the U.S., the headlamp photometry would need to be modified, which would entail some design cost. This is true for any European-model vehicle sold in the U.S.

XII. Rulemaking Analyses

Executive Order 13771

Executive Order 13771 titled "Reducing Regulation and Controlling Regulatory Costs," directs that, unless prohibited by law, whenever an executive department or Agency publicly proposes for notice and comment or otherwise promulgates a new regulation, it shall identify at least two existing regulations to be repealed. In addition, any new incremental costs associated with new regulations shall, to the extent permitted by law, be offset by the elimination of existing costs. Only those rules deemed significant under section 3(f) of Executive Order 12866, "Regulatory Planning and Review," are subject to these requirements. As discussed below, this rule is not a significant rule under Executive Order 12866. However, this proposed rule is expected to be an E.O. 13771 deregulatory action. Details on the estimated cost savings of this proposed rule can be found in the rule's economic analysis.

Executive Order 12866, Executive Order 13563, and DOT Regulatory Policies and Procedures

Executive Order 12866, Executive Order 13563, and the Department of Transportation's regulatory policies require determinations as to whether a regulatory action is "significant" and therefore subject to OMB review and the requirements of the aforementioned Executive Orders. Executive Order 12866 defines a "significant regulatory action" as one that is likely to result in a rule that may:

(1) Have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or Tribal governments or communities;

(2) Create a serious inconsistency or otherwise interfere with an action taken or planned by another agency;

(3) Materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of recipients thereof; or

(4) Raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in the Executive Order.

We have considered the potential impact of this proposal under Executive Order 12866, Executive Order 13563, and the Department of Transportation's regulatory policies and procedures. This NPRM is not significant and so was not reviewed under E.O. 12866.

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However, pursuant to E.O. 12866 and the Department's policies, we have identified the problem this NPRM intends to address, considered whether existing regulations have contributed to the problem, and considered alternatives. Because this rulemaking has been designated nonsignificant, quantification of benefits is not required under E.O. 12866, but is required, to the extent practicable, under DOT Order 2100.5. NHTSA has tentatively determined that quantifying the benefits and costs is not practicable in this rulemaking.

Quantifying the benefits of the proposal—the decrease in deaths and injuries due to the greater visibility made possible by ADB—is difficult because of a variety of data limitations related to accurately estimating the target population and the effectiveness of ADB. For example, headlamp state (on-off, upper-lower beam) is not reflected in the data for many of the pedestrian crashes. Nevertheless, we attempt to broadly estimate the magnitude of the target population in Appendix A. (Toyota's rulemaking petition also includes a target population analysis using a different methodology.)

Quantification of costs is similarly not practicable. The only currently-available ADB systems are in foreign markets such as Europe. We tentatively believe that an ECE-approved ADB system (modified to have FMVSS 108-compliant photometry) would be able to comply with the proposed requirements. It would be possible for NHTSA to estimate the cost of such systems by performing teardown studies, but we have not done so. Among other reasons, even if NHTSA performed tear-down studies for ECE-approved systems, NHTSA would still need to estimate the cost of the compliance with the main regulatory alternative, SAE J3069. However, there are not any SAE J3069-compliant systems on the market to use in a tear-down cost analysis because ADB systems are not currently available in the U.S. It might be possible for NHTSA to estimate the costs of an SAE J3069-compliant system with an engineering assessment, but such an assessment would require additional time and resources.

We therefore tentatively conclude that a quantitative cost-benefit analysis is not currently practicable. We believe that a qualitative analysis (see Section XI, Overview of Benefits and Costs) is sufficient to reasonably conclude that the proposed requirements are preferable to the current regulatory alternative.

Executive Order 13609: Promoting International Regulatory Cooperation

The policy statement in section 1 of Executive Order 13609 provides, in part:

> The regulatory approaches taken by foreign governments may differ from those taken by U.S. regulatory agencies to address similar issues. In some cases, the differences between the regulatory approaches of U.S. agencies and those of their foreign counterparts might not be necessary and might impair the ability of American businesses to export and compete internationally. In meeting shared challenges involving health, safety, labor, security, environmental, and other issues, international regulatory cooperation can identify approaches that are at least as protective as those that are or would be adopted in the absence of such cooperation. International regulatory cooperation can also reduce, eliminate, or prevent unnecessary differences in regulatory requirements.

Although this proposal is different than comparable foreign regulations, we believe that the proposed requirements have the potential to enhance safety.

Executive Order 13132 (Federalism)

NHTSA has examined this proposed rule pursuant to Executive Order 13132 (64 FR 43255; Aug. 10, 1999) and concluded that no additional consultation with States, local governments, or their representatives is mandated beyond the rulemaking process. The Agency has concluded that the rule does not have sufficient federalism implications to warrant consultation with State and local officials or the preparation of a federalism summary impact statement. The rule does not have "substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government."

NHTSA rules can have preemptive effect in two ways. First, the National Traffic and Motor Vehicle Safety Act contains an express preemption provision: When a motor vehicle safety standard is in effect under this chapter, a State or a political subdivision of a State may prescribe or continue in effect a standard applicable to the same aspect of performance of a motor vehicle or motor vehicle equipment only if the standard is identical to the standard prescribed under this chapter. 49 U.S.C. 30103(b)(1). It is this statutory command by Congress that preempts any non-identical State legislative and administrative law address the same aspect of performance.

The express preemption provision described above is subject to a savings clause under which "[c]ompliance with a motor vehicle safety standard prescribed under this chapter does not exempt a person from liability at common law." 49 U.S.C. 30103(e) Pursuant to this provision, State common law tort causes of action against motor vehicle manufacturers that might otherwise be preempted by the express preemption provision are generally preserved. However, the Supreme Court has recognized the possibility, in some instances, of implied preemption of State common law tort causes of action by virtue of NHTSA's rules—even if not expressly preempted.

This second way that NHTSA rules can preempt is dependent upon the existence of an actual conflict between an FMVSS and the higher standard that would effectively be imposed on motor vehicle manufacturers if someone obtained a State common law tort judgment against the manufacturer—notwithstanding the manufacturer's compliance with the NHTSA standard. Because most NHTSA standards established by an FMVSS are minimum standards, a State common law tort cause of action that seeks to impose a higher standard on motor vehicle manufacturers will generally not be preempted. However, if and when such a conflict does exist—for example, when the standard at issue is both a minimum and a maximum standard—the State common law tort cause of action is impliedly preempted. See *Geier* v. *American Honda Motor Co.*, 529 U.S. 861 (2000).

Pursuant to Executive Order 13132, NHTSA has considered whether this proposed rule could or should preempt State common law causes of action. The Agency's ability to announce its conclusion regarding the preemptive effect of one of its rules reduces the likelihood that preemption will be an issue in any subsequent tort litigation.

To this end, the Agency has examined the nature (*e.g.*, the language and structure of the regulatory text) and objectives of this proposed rule and does not foresee any potential State requirements that might conflict with it. We do note that many or most states have laws that regulate lower and upper beam use. These laws require that a motorist use a lower beam within a certain distance of an oncoming or preceding vehicle. We do not believe that there is a conflict between the proposed rule and these laws because the proposed rule would allow an additional type of lower beam. A vehicle equipped with a compliant and properly functioning ADB system should not glare other vehicles, as long

as the proposed requirements are sufficient to meet the goals of this proposal—*i.e.*, to protect oncoming and preceding motorists from glare. NHTSA does not intend that this proposed rule preempt state tort law that would effectively impose a higher standard on motor vehicle manufacturers than that established by this rule. Establishment of a higher standard by means of State tort law would not conflict with the standards proposed in this NPRM. Without any conflict, there could not be any implied preemption of a State common law tort cause of action.

National Environmental Policy Act

The National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321–4347) requires Federal agencies to analyze the environmental impacts of proposed major Federal actions significantly affecting the quality of the human environment, as well as the impacts of alternatives to the proposed action. 42 U.S.C. 4332(2)(C). When a Federal agency prepares an environmental assessment, the Council on Environmental Quality (CEQ) NEPA implementing regulations (40 CFR parts 1500–1508) require it to "include brief discussions of the need for the proposal, of alternatives [. . .], of the environmental impacts of the proposed action and alternatives, and a listing of agencies and persons consulted." 40 CFR 1508.9(b). This section serves as the Agency's Draft Environmental Assessment (Draft EA). NHTSA invites public comments on the contents and tentative conclusions of this Draft EA.

Purpose and Need

This notice of proposed rulemaking sets forth the purpose of and need for this action. As explained earlier in this preamble, ADB technology improves safety by providing a variable, enhanced lower beam pattern that is sculpted to traffic on the road, rather than just one static lower beam pattern, thereby providing more illumination without glare to other motorists. In addition, ADB technology will likely lead to increased upper beam use, thereby improving driver visibility distance at higher speeds. In this document, NHTSA tentatively concludes that FMVSS No. 108 does not currently permit ADB technology. This proposal therefore reconsiders the currently-existing standard by addressing the safety needs of visibility and glare prevention to improve safety. This proposal considers and invites comment on how best to ensure that ADB technology improves visibility without increasing glare.

Alternatives

NHTSA has considered a range of regulatory alternatives for the proposed action. Under a "no action alternative," NHTSA would not issue a final rule amending FMVSS No. 108, and ADB technology would continue to be prohibited. NHTSA has also considered the ECE requirements and SAE J3069, which are described above in this preamble. Under this proposal, NHTSA incorporates elements from these standards, but departs from them in significant ways, which are also described above. NHTSA invites public comments on its proposal.

Environmental Impacts of the Proposed Action and Alternatives

This proposed action is anticipated to result in increased upper beam use as well as greater illumination from lower beams (albeit in patterns designed to prevent glare to other motorists). As a result, the primary environmental impacts anticipated to result from this rulemaking are associated with light pollution, including the potential disruption of wildlife adjacent to roadways. The National Park Service (NPS) defines "light pollution" as the introduction of artificial light, either directly or indirectly, into the natural environment.[137] Forms of light pollution include sky glow (the bright halo over urban areas at nighttime), light trespass (unintended artificial lighting on areas that would otherwise be dark), glare (light shining horizontally), and overillumination (excess artificial lighting for a specific activity).[138] Light pollution caused by artificial light can have various effects on flora and fauna, including disrupting seasonal variations and circadian rhythms, disorientation and behavioral disruption, sleep disorders, and hormonal imbalances.[139]

Although this rule is anticipated to result in increased levels of illumination caused by automobiles at nighttime, NHTSA does not believe these levels would contribute appreciably to light pollution in the United States. First, the Agency proposes to require that the part of an ADB beam that is cast near other vehicles not exceed the current low beam maxima and the part of an ADB beam that is cast onto unoccupied roadway not exceed the current upper beam maxima. Although overall levels of illumination are expected to increase from current levels due to increased high beam use and the sculpting of lower beams to traffic on the road, total potential brightness would not be permitted to exceed the potential maxima that already exists on motor vehicles today. These maxima would not only reduce the potential for glare to other drivers, but would also limit the potential impact of light pollution.

Second, we note that ADB systems remain optional under the proposal. Because of the added costs associated with the technology, NHTSA does not anticipate that manufacturers would make these systems standard equipment in all of their vehicle models at this time. Thus, only a percentage of the on-road fleet would feature ADB systems, while new vehicles without the systems would be anticipated to continue to have levels of illumination at current rates.

Third, while ADB systems generally would increase horizontal illumination, they likely would not contribute to ambient light pollution to the same degree as other forms of illumination, such as streetlights and building illumination, where light is intentionally scattered to cover large areas or wasted due to inefficient design, likely contributing more to the nighttime halo effect in populated areas. According to NPS, the primary cause of light pollution is outdoor lights that emit light upwards or sideways (but with an upwards angle).[140] As the light escapes upward, it scatters throughout the atmosphere and brightens the night sky. Lighting that is directed downward, however, contributes significantly less to light pollution. Lower beams generally direct light away from oncoming traffic and downward in order to illuminate the road and the environs close ahead of the vehicle while minimizing glare to other road users. As a result, any increases in lower beam illumination are not anticipated to contribute meaningfully to light pollution. As discussed further in the next paragraph, increases in upper beam illumination would be anticipated largely in less populated areas, where oncoming traffic is less frequent and small sources of artificial light (such as motor vehicles) likely would not change ambient light levels at nighttime to a meaningful degree.

Fourth, NHTSA believes that the areas that would see the greatest relative increase in nighttime illumination are predominantly rural and unlikely to experience widespread impacts. The

[137] National Park Service, Light Pollution. *https://www.nps.gov/subjects/nightskies/lightpollution.htm* (last accessed Sept. 26, 2018).

[138] Chepesiuk, R. 2009. Missing the Dark: Health Effects of Light Pollution. *Environmental Health Perspectives,* 117(1), A20–A27.

[139] *Id.*

[140] NPS, Light Pollution Sources. *https://www.nps.gov/subjects/nightskies/sources.htm* (last accessed Sept. 26, 2018).

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Agency's proposal would require ADB systems to produce a base lower beam at speeds below 25 mph. These slower speeds are anticipated primarily in crowded, urban environments where the current impacts of light pollution are likely the greatest. As a result, such urban environments would not experience changes in light levels produced from motor vehicles as a result of this proposal. In moderately crowded, urban environments, nighttime vehicles may travel above 25 mph, thereby engaging the ADB system. However, in those cases, upper beam use would likely be low, as the high level of other road users would cause the ADB system to rely on lower beams for visibility in order to reduce glare for other drivers. These areas may experience small increases in light pollution as the upper beams occasionally engage, as well as increased illumination associated with lower beam shaping by the ADB system. In rural areas, where traffic levels are lower and driving speeds may be higher, the use of ADB systems is anticipated to result in increased upper beam use. However, the low traffic levels would result in only moderate additional light output, and the low quantity of artificial light sources in general would mean that light pollution levels overall would be anticipated to remain low.

The proposed action is anticipated to improve visibility without glare to other drivers. In addition to the potential safety benefits associated with reduced crashes, this rule could result in fewer instances of collisions involving animals on roadways. Upper beams are used primarily for distance illumination when not meeting or closely following another vehicle. Increased upper beam use in poorly lit environments, such as rural roadways, may allow drivers increased time to identify roadway hazards (such as animals) and to stop, slow down, or avoid a collision.

In addition, the impact of added artificial light on wildlife located near roadways would depend on where and how long the additional illumination occurs, whether or not wildlife is present within a distance to detect the light, and the sensitivity of wildlife to the illumination level of the added light. Wildlife species located near active roadways have likely acclimated to the light produced by passing vehicles, including light associated with upper beams (which would be the same under the proposal in terms of brightness, directionality, and shape as under current regulations). Any additional disruption caused by increased use of upper beams is not feasible to quantify due to the extensive number of variables associated with ADB use and wildlife.

NHTSA is unable to comparatively evaluate the potential light pollution impacts of the proposal compared to the other regulatory alternatives (ECE requirements and SAE J3069). For example, the proposal requires that the undimmed portion of the adaptive beam meet the upper beam minima and the dimmed portion of the beam meet the lower beam minima. The SAE standard does not establish minima for either condition. However, NHTSA also proposes that the undimmed portion of the beam may not exceed the upper beam maxima, whereas the SAE standard does not specify an upper beam maxima for the undimmed portion. Thus, while NHTSA proposes more stringent requirements for ADB systems, the wide variations still permitted under the proposal and the SAE standards make it difficult to compare them with any level of certainty. However, to the degree to which ABD systems would function similarly under each of those standards, the environmental impacts would be anticipated to be similar.

NHTSA seeks comment on its analysis of the potential environmental impacts of its proposal, which will be reviewed and considered in the preparation of a Final EA.

Agencies and Persons Consulted

This preamble describes the various materials, persons, and agencies consulted in the development of the proposal.

Tentative Conclusion

NHTSA has reviewed the information presented in this Draft EA and tentatively concludes that the proposed action would not contribute in a meaningful way to light pollution as compared to current conditions. Any of the impacts anticipated to result from the alternatives under consideration are not expected to rise to a level of significance that necessitates the preparation of an Environmental Impact Statement. Based on the information in this Draft EA and assuming no additional information or changed circumstances, NHTSA expects to issue a Finding of No Significant Impact (FONSI). Such a finding will not be made before careful review of all public comments received. A Final EA and a FONSI, if appropriate, will be issued as part of the final rule.

Executive Order 12988 (Civil Justice Reform)

With respect to the review of the promulgation of a new regulation, section 3(b) of Executive Order 12988, "Civil Justice Reform" (61 FR 4729, February 7, 1996) requires that Executive agencies make every reasonable effort to ensure that the regulation: (1) Clearly specifies the preemptive effect; (2) clearly specifies the effect on existing Federal law or regulation; (3) provides a clear legal standard for affected conduct, while promoting simplification and burden reduction; (4) clearly specifies the retroactive effect, if any; (5) adequately defines key terms; and (6) addresses other important issues affecting clarity and general draftsmanship under any guidelines issued by the Attorney General. This document is consistent with that requirement.

Pursuant to this Order, NHTSA notes as follows. The issue of preemption is discussed above in connection with E.O. 13132. NHTSA notes further that there is no requirement that individuals submit a petition for reconsideration or pursue other administrative proceeding before they may file suit in court.

Regulatory Flexibility Act

Pursuant to the Regulatory Flexibility Act (5 U.S.C. 601 *et seq.*, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996), whenever an agency is required to publish an NPRM or final rule, it must prepare and make available for public comment a regulatory flexibility analysis (RFA) that describes the effect of the rule on small entities (*i.e.*, small businesses, small organizations, and small governmental jurisdictions). The Small Business Administration's regulations at 13 CFR part 121 define a small business, in part, as a business entity "which operates primarily within the United States." (13 CFR 121.105(a)). No regulatory flexibility analysis is required if the head of an agency certifies that the rule will not have a significant economic impact on a substantial number of small entities. The SBREFA amended the Regulatory Flexibility Act to require Federal agencies to provide a statement of the factual basis for certifying that a rule will not have a significant economic impact on a substantial number of small entities.

NHTSA has considered the effects of this rulemaking action under the Regulatory Flexibility Act. According to 13 CFR 121.201, the Small Business Administration's size standards regulations used to define small business concerns, manufacturers of the vehicles covered by this proposed rule would fall under North American Industry Classification System (NAICS) No. 336111, *Automobile Manufacturing,*

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which has a size standard of 1,000 employees or fewer.

NHTSA estimates that there are six small light vehicle manufacturers in the U.S. We estimate that there are eight headlamp manufacturers that could be impacted by a final rule. I hereby certify that if made final, this proposed rule would not have a significant economic impact on a substantial number of small entities. Most of the affected entities are not small businesses. The proposed rule, if adopted, will not establish a mandatory requirement on regulated persons.

National Technology Transfer and Advancement Act

Under the National Technology Transfer and Advancement Act of 1995 (NTTAA) (Pub. L. 104–113), "all Federal agencies and departments shall use technical standards that are developed or adopted by voluntary consensus standards bodies, using such technical standards as a means to carry out policy objectives or activities determined by the agencies and departments." Voluntary consensus standards are technical standards (*e.g.*, materials specifications, test methods, sampling procedures, and business practices) that are developed or adopted by voluntary consensus standards bodies, such as the Society of Automotive Engineers (SAE). The NTTAA directs this Agency to provide Congress, through OMB, explanations when the Agency decides not to use available and applicable voluntary consensus standards.

SAE International has published a voluntary consensus standard (SAE J3069 JUN2016) for ADB systems. The foregoing sections of this document discuss in detail areas in which we follow or depart from SAE J3069.

Paperwork Reduction Act

Under the Paperwork Reduction Act of 1995 (PRA) (44 U.S.C. 3501, *et seq.*), Federal agencies must obtain approval from the Office of Management and Budget (OMB) for each collection of information they conduct, sponsor, or require through regulations. This rulemaking would not establish any new information collection requirements.

Unfunded Mandates Reform Act

The Unfunded Mandates Reform Act of 1995 (Pub. L. 104–4) (UMRA) requires agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditures by States, local or tribal governments, in the aggregate, or by the private sector, of more than $100 million annually (adjusted annually for inflation with base year of 1995). Adjusting this amount by the implicit gross domestic product price deflator for 2013 results in $142 million (109.929/75.324 = 1.42). The assessment may be included in conjunction with other assessments, as it is here.

This proposed rule is not likely to result in expenditures by State, local or tribal governments of more than $100 million annually.

UMRA requires the Agency to select the "least costly, most cost-effective or least burdensome alternative that achieves the objectives of the rule." As discussed above, the Agency considered alternatives to the proposed rule. We have tentatively concluded that none of the alternatives are preferable to the alternative proposed by the NPRM. We have tentatively concluded that the requirements we are proposing today are the most cost-effective alternatives that achieve the objectives of the rule.

Plain Language

Executive Order 12866 and E.O. 13563 require each agency to write all rules in plain language. Application of the principles of plain language includes consideration of the following questions:

- Have we organized the material to suit the public's needs?
- Are the requirements in the rule clearly stated?
- Does the rule contain technical language or jargon that isn't clear?
- Would a different format (grouping and order of sections, use of headings, paragraphing) make the rule easier to understand?
- Would more (but shorter) sections be better?
- Could we improve clarity by adding tables, lists, or diagrams?
- What else could we do to make the rule easier to understand?

If you have any responses to these questions, please include them in your comments on this proposal.

Regulation Identifier Number (RIN) 2127–AL83

The Department of Transportation assigns a regulation identifier number (RIN) to each regulatory action listed in the Unified Agenda of Federal Regulations. The Regulatory Information Service Center publishes the Unified Agenda in April and October of each year. You may use the RIN contained in the heading at the beginning of this document to find this action in the Unified Agenda.

Privacy Act

Anyone is able to search the electronic form of all comments received into any of our dockets by the name of the individual submitting the comment (or signing the comment, if submitted on behalf of an association, business, labor union, etc.). You may review DOT's complete Privacy Act Statement in the **Federal Register** published on April 11, 2000 (65 FR 19477–78).

XIII. Public Participation

How do I prepare and submit comments?

Your comments must be written and in English. To ensure your comments are correctly filed in the Docket, please include the docket number of this document in your comments.

Please organize your comments so they appear in the same order as the topic to which they respond appears in the preamble. Please number comments as they are numbered in the preamble. For example, a comment concerning the placement of the photometer on an oncoming vehicle might be labeled "VIII.b.ii.3.a—Photometer Placement for Oncoming Vehicles," or "VIII.b.ii.3—Photometer Placement."

Your comments must not be more than 15 pages long. (49 CFR 553.21). We established this limit to encourage you to write your primary comments in a concise fashion. However, you may attach necessary additional documents to your comments. There is no limit on the length of the attachments.

Comments may also be submitted to the docket electronically by logging onto the Docket website at *http://www.regulations.gov*. Follow the online instructions for submitting comments.

Please note pursuant to the Data Quality Act, for substantive data to be relied upon and used by the Agency, it must meet the information quality standards set forth in the OMB and DOT Data Quality Act guidelines. Accordingly, we encourage you to consult guidelines in preparing your comments. OMB's guidelines may be accessed at *http://www.whitehouse.gov/omb/fedreg/reproducible.html*.

How can I be sure that my comments were received?

If you wish the Docket to notify you upon its receipt of your comments, enclose a self-addressed, stamped postcard in the envelope containing your comments. Upon receiving your comments, the Docket will return the postcard by mail.

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How do I submit confidential business information?

If you wish to submit any information under a claim of confidentiality, you should submit three copies of your complete submission, including the information you claim to be confidential business information, to the Chief Counsel, NHTSA, at the address given above under **FOR FURTHER INFORMATION CONTACT**. In addition, you should submit a copy, from which you have deleted the claimed confidential business information, to the docket at the address given above under **ADDRESSES**. When you send a comment containing information claimed to be confidential business information, you should include a cover letter setting forth the information specified in our confidential business information regulation. (49 CFR part 512.)

Will the Agency consider late comments?

We will consider all comments received before the close of business on the comment closing date indicated above under **DATES**. To the extent possible, we will also consider comments the docket receives after that date. If the docket receives a comment too late for us to consider in developing a final rule (assuming that one is issued), we will consider that comment as an informal suggestion for future rulemaking action.

How can I read the comments submitted by other people?

You may read the comments received by the docket at the address given above under **ADDRESSES**. The hours of the docket are indicated above in the same location. You may also see the comments on the internet. To read the comments on the internet, go to *http://www.regulations.gov*. Follow the online instructions for accessing the dockets.

Please note: Even after the comment closing date, we will continue to file relevant information in the docket as it becomes available. Further, some people may submit late comments. Accordingly, we recommend that you periodically check the Docket for new material. You can arrange with the docket to be notified when others file comments in the docket. See *www.regulations.gov* for more information.

XIV. Appendix A to Preamble—Road Illumination and Pedestrian/Cyclist Fatalities

The Agency examined crash risk that could reasonably be linked to vehicle headlighting to demonstrate the safety issue which ADB optional equipment could potentially impact. We explored the correlations between pedestrian and cyclist fatalities (FARS 2006–2016 data) and light conditions, as well as the correlations between pedestrian and cyclist injuries (GES 2006–2016 data) and light conditions. Then the ratios of pedestrian/cyclist fatalities over injuries were also examined. The Agency tentatively believes that a higher ratio of fatalities to injuries demonstrates among potential other influences, driver recognition and attempts to avoid these crashes. The basic concept is that limited visibility can result in late reactions and deadly crashes.

The following tables indicate combined pedestrian and cyclist fatalities, associated with light vehicle (<=10,000 lbs.) crashes only and in "all areas" (rural, urban, and others), decreased from 4,755 in 2006 to the lowest number of 4,130 in 2009, but the fatalities increased steadily from 2009 to the highest number of 5,912 in 2016. In particular, there was an increase of 7.1% from 2015 to 2016 in pedestrian and cyclist fatalities.

TABLE A.1—LIGHT CONDITION PEDESTRIAN/CYCLIST FATALITIES FROM FARS 2006–2016

[Light vehicle types <=10,000 lbs.]

Year	Day light	Dark	Dark but lighted	Dawn	Dust	Dark & ukn. light	Others	Not-rept.	Unknown	Total fatalities
2006	1,386	1,561	1,571	92	128	0	0	0	17	4,755
2007	1,433	1,472	1,495	66	98	0	0	0	18	4,582
2008	1,285	1,425	1,463	79	122	0	0	0	13	4,387
2009	1,252	1,199	1,463	71	97	39	0	0	9	4,130
2010	1,254	1,321	1,483	77	84	45	5	2	5	4,276
2011	1,247	1,402	1,569	57	113	35	4	3	8	4,438
2012	1,335	1,589	1,726	79	105	29	2	3	6	4,874
2013	1,336	1,532	1,641	74	113	25	1	5	7	4,734
2014	1,393	1,615	1,697	90	111	25	4	2	10	4,947
2015	1,453	1,789	1,973	91	135	67	2	3	6	5,519
2016	1,499	1,905	2,183	88	138	72	2	3	22	5,912
Total	14,873	16,810	18,264	864	1,244	337	20	21	121	52,554

In addition to the fatality data, GES 2006–2016 data are used to explore how many pedestrians and cyclists were injured (*e.g.*, 'severity' not equal zero) under various light conditions. With both FARS and GES data, we are then able to calculate the ratio of 'fatalities over injuries' (Fatality Rate) under various light conditions, to compare the relative fatality rates (%) under various light conditions.

TABLE A.2—GES 2006–2016 WEIGHTED INJURED PEDESTRIAN/CYCLISTS

[Light vehicle types <=10,000 lbs. only]

Year	Day light	Dark	Dark but lighted	Dawn	Dust	Dark & ukn. light	Others	Not-rept.	Unknown	Total injuries
2006	67,100	9,288	22,531	1,582	4,333	0	0	0	1,471	106,305
2007	71,729	8,285	28,216	1,404	4,010	0	0	0	736	114,379
2008	84,521	8,889	22,009	1,606	3,179	0	0	0	1,209	121,414
2009	73,771	8,037	24,157	1,588	2,935	1,376	20	0	260	112,142

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TABLE A.2—GES 2006–2016 WEIGHTED INJURED PEDESTRIAN/CYCLISTS—Continued

[Light vehicle types <=10,000 lbs. only]

Year	Day light	Dark	Dark but lighted	Dawn	Dust	Dark & ukn. light	Others	Not-rept.	Unknown	Total injuries
2010	84,670	6,359	25,808	2,946	4,400	537	0	106	99	124,925
2011	80,876	7,344	27,996	2,056	3,373	292	0	436	379	122,753
2012	80,933	8,864	33,913	707	4,192	499	12	377	81	129,579
2013	74,277	8,305	28,805	960	4,181	457	15	47	116	117,161
2014	77,258	8,901	28,520	1,326	4,604	347	11	293	54	121,316
2015	76,817	9,074	27,223	1,627	3,268	602	15	401	73	119,099
2016	96,861	12,922	34,791	2,361	4,549	1,378	0	406	287	153,556
Total	868,813	96,267	303,969	18,163	43,024	5,488	73	2,065	4,766	1,342,629

From the previous fatalities and injuries tables, the following table provides ratios of fatalities over injuries (fatality rates) under various light conditions. 'Dark' condition resulted in the highest fatality rate. In other words, the following table provides the probability or risk of pedestrian/cyclist fatality under certain light condition when a crash occurred, which could further lead to the relative risk (RR) comparison of two different light conditions.

Table A.3

Fatalities over Injuries Ratios of Pedestrians/Cyclists

(FARS 2006-16, and all injuries: GES 2006-16)

Counts	Day Light	Dark	Dark but Lighted	Dawn	Dusk	Dark & unkn. light	Other	Not-report	Unknown	Total Fatalities
Fatalities (FARS)	14,873	16,810	18,264	864	1,244	337	20	21	121	52,554
Injuries (GES)	868,813	96,267	303,969	18,163	43,024	5,488	73	2,065	4,766	1,342,629
Ratio of (fatalities /injuries)	1.71%	17.46%	6.00%	4.76%	2.89%	6.14%	27.40%	1.02%	2.54%	3.91%

These tables indicate that there are 16,810 pedestrian and cyclist fatalities under 'Dark' condition (FARS 2006–16); under the same condition, GES data (2006–2015) indicate there are 96,267 injured pedestrians/cyclists. The fatality rate, *e.g.*, fatalities/injured persons = 17.46% ('Dark' condition). Similarly, there are 18,264 pedestrian and cyclist fatalities under 'Dark but Lighted' condition and 303,969 injured pedestrians and cyclists, which resulting in a ratio of 6.00% (in "Dark but lighted" condition).

The Agency first noted the trend within these unfiltered ratios seeming to indicate the possible relationship between the amount of light available to a driver and the fatality risk to pedestrians and cyclists. That is to say, if we examine fatalities rates for 'Daylight' (1.71%), 'Dark but lighted' (6.00%), and 'Dark' (17.46%), and assume these represent decreasing visibility, we note there appears to be an inverse relationship between the amount of light available and the odds for a pedestrian or cyclist being killed if a crash occurs.

However, light condition may not be the only risk factor contributing to the pedestrian/cyclist fatality rate but many other confounding factors may simultaneously contribute to different fatality rates under different light conditions. Other confounding factors may include driver or pedestrian behaviors, vehicle type, travel speed, road condition, driver drinking status, rural/urban difference, EMS, person age/health condition, and more. The next table examines a similar fatality rate comparison made by focusing on a smaller target population of 'non-

drinking' crashes only because it is likely light condition and drunk driving are themselves related.

TABLE A.4—PEDESTRIAN/CYCLIST FATALITIES INCLUDING 'DRIVER NOT DRINKING' CRASHES ONLY

[Light VEH <=10,000 lbs, FARS 2006–16]

Year	Day light	Dark	Dark but lighted
2006	1,302	1,369	1,335
2007	1,351	1,294	1,267
2008	1,200	1,250	1,263
2009	1,167	1,050	1,257
2010	1,194	1,180	1,265
2011	1,162	1,245	1,336
2012	1,256	1,431	1,493
2013	1,254	1,378	1,439
2014	1,305	1,474	1,472
2015	1,372	1,642	1,762
2016	1,413	1,752	1,936
Total	13,976	15,065	15,825

TABLE A.5—PEDESTRIAN/CYCLIST INJURIES (INJ SEV NOT ZERO) INCLUDING 'DRIVER NOT-DRINKING CRASHES' ONLY

[Light veh. <=10, 000 lbs. and GES 2006–16]

Year	Day light	Dark	Dark but lighted
2006	63,535	7,929	19,083
2007	69,553	7,479	26,293
2008	81,003	8,161	19,560
2009	71,870	7,184	22,758
2010	84,006	6,144	24,672
2011	79,471	7,088	26,387
2012	79,724	8,519	32,113
2013	72,970	7,811	25,655
2014	76,201	8,533	27,474

TABLE A.5—PEDESTRIAN/CYCLIST INJURIES (INJ SEV NOT ZERO) INCLUDING 'DRIVER NOT-DRINKING CRASHES' ONLY—Continued

[Light veh. <=10, 000 lbs. and GES 2006–16]

Year	Day light	Dark	Dark but lighted
2015	75,831	8,558	26,409
2016	95,226	11,915	33,339
Total	849,390	89,321	283,743

TABLE A.6—RATIOS OF PEDESTRIAN/CYCLIST FATALITIES OVER INJURIES INCLUDING 'NOT-DRINKING DRIVER' CRASHES ONLY DURING 2006–2016 AND LIGHT VEHICLES <=10,000 LBS.

Year	Day light	Dark	Dark but lighted
Fatalities	13,976	15,065	15,825
Injuries	849,390	89,321	283,743
Ratio of (fatalities/injuries)	1.65%	16.87%	5.58%

In examining previous tables, we note the trend demonstrating an inverse relationship between light and the fatality risk for pedestrians continues for crashes not involving alcohol. If our hypothesis considering long distance visibility contributes to the fatality risk to pedestrians and cyclists, then we should also expect a relationship between speed, light, and fatality risk. That is to say, we would expect that at low speeds, a driver may be more likely to react in time to overcome limited visibility and mitigate crash severity but less likely to be able to reduce crash severity at higher speeds. The following analysis considers both speed limit and light condition.

Correlations between the pedestrian/cyclist fatal probability and risk factors could be described by the following equation, where 'p' stands for the probability of 'pedestrian/cyclist fatality', '1-p' stands for the probability of 'pedestrian/cyclist non-fatality', and 'p/(1-p)' is the 'odds' of the crash resulting in 'pedestrian/cyclist fatality' versus 'pedestrian/cyclist non-fatality'. We conducted a multiple logistic model that included 'light condition', 'speed limit' and 'drinking' into the consideration simultaneously. The logit model provides the odds ratio (OR) of two different crash conditions associated with each predictor variable, such as comparing the better light condition with darker light condition; comparing higher speed limit (+5 MPH) with next lower speed limit; and comparing the alcohol involved crash with not-alcohol involved crash. The OR value of larger than 1.0 indicates the higher chance of pedestrian/cyclist fatality while less than 1.0 for lower chance of pedestrian fatality. The model treats pedestrian/cyclist fatal crash as 'outcome', in which FARS 2006–2016 fatalities and GES 2006–16 injuries are used.

$$\frac{p}{1-p} = \exp(\beta_0 + \beta_1 LightCondition + \beta_2 SpeedLimit + \beta_3 Drinking)$$

Or, the probability of pedestrian/cyclist fatality is expressed by:

$$p = \frac{\exp(\beta_0 + \beta_1 LightCondition + \beta_2 SpeedLimit + \beta_3 Drinking)}{1 + \exp(\beta_0 + \beta_1 LightCondition + \beta_2 SpeedLimit + \beta_3 Drinking)}$$

TABLE A.7—PEDESTRIAN/CYCLIST FATALITY ODDS RATIOS FROM LIGHT CONDITION AND SPEED LIMIT

Comparison between two different light conditions	Odds ratio (OR) point estimate	95% OR confidence lower	95% OR confidence upper	P-value
'dawn or dust' vs. 'day light'	1.930	1.781	2.092	<0.0001
'dark but lighted' vs. 'day light'	2.711	2.596	2.830	<0.0001
'dark' vs 'day light'	5.004	4.807	5.209	<0.0001
higher speed limit (5 MPH)	1.512	1.490	1.534	<0.0001
Drinking versus NOT	1.965	1.849	2.087	<0.0001

ANALYSIS OF MAXIMUM LIKELIHOOD ESTIMATES AND PARAMETER ESTIMATE OF EQ.

Comparison between two different light conditions	Parameter estimate (β_i)	Standard error	Wald chi-sqare	P-value
intercept	−2.8634	0.0295	9397.9	<0.0001

ANALYSIS OF MAXIMUM LIKELIHOOD ESTIMATES AND PARAMETER ESTIMATE OF EQ.—Continued

Comparison between two different light conditions	Parameter estimate (β_i)	Standard error	Wald chi-sqare	P-value
'dawn or dust' vs. 'day'	−0.586	0.0292	29.4	<0.0001
'dark but lighted' vs. 'day'	0.1809	0.0157	132.1	<0.0001
'dark' vs 'day'	0.7940	0.0147	2904.1	<0.0001
higher speed limit (5 MPH)	0.4133	0.00734	3174.6	<0.0001
'Drinking' vs 'not-drinking'	0.6753	0.0309	477.97	<0.0001

When fatality chances under two different light conditions are compared, the pedestrian/cyclist fatality chance under 'dawn or dusk' condition is 2 times the fatality chance under 'day light' condition (OR = 1.93); similarly, the pedestrian/cyclist fatality chance under 'dark' condition is 5 times the fatality chance under 'day light' (OR = 5.00); the fatality chance under 'dark' condition is 1.87 times (5.00/2.7 = 1.85) the fatality chance under 'dark but lighted' condition, or in other words, the fatality chance under 'dark but lighted' condition is approximately 54% (2.70/5.00 = 0.53) of the fatality chance of 'dark' condition. This analysis seems to indicate an improvement of light conditions could be helpful for improving and reducing fatality probability. With a higher speed limit (+5 MPH), the pedestrian/cyclist fatality chance is 51% higher (OR = 1.51) approximately. Drinking may result in 2.0 times fatality rate.

List of Subjects in 49 CFR Part 571

Motor vehicle safety, Reporting and recordkeeping requirements, Rubber and rubber products.

Proposed Regulatory Text

In consideration of the foregoing, 49 CFR part 571 is proposed to be amended as set forth below.

PART 571—FEDERAL MOTOR VEHICLE SAFETY STANDARDS

■ 1. The authority citation for part 571 of title 49 continues to read as follows:

Authority: 49 U.S.C. 322, 30111, 30115, 30117, 30166; delegation of authority at 49 CFR 1.95.

■ 2. Amend § 571.108 by:
■ a. Revising paragraphs S9.4.1, S9.4.1.1, S9.4.1.2, S9.4.1.3, S9.4.1.4, and S9.4.1.5;
■ b. Adding paragraphs S9.4.1.5.1 through S9.4.1.5.3 in numerical order;
■ c. Revising paragraph S9.4.1.6;
■ d. Adding paragrpahs S9.4.1.6.1 through S9.4.1.6.8 in numerical order;
■ e. Removing S9.4.1.7;
■ f. Revising paragraph S9.5;
■ g. Adding paragraphs S14.9.3.12 through S14.9.3.12.8.1, tables XIX–d and XXI, and figures 23 through 25 in numerical order; and
■ b. Removing the appendix to the section.

The revisions and additions read as follows:

§ 571.108 Standard No. 108; Lamps, reflective devices, and associated equipment.

* * * * *

S9.4.1 *Semiautomatic headlamp beam switching devices.* As an alternative to S9.4, a vehicle may be equipped with a semiautomatic means of switching between lower and upper beams that complies with 9.4.1.1 though S9.4.1.4 and either 9.4.1.5 or 9.4.1.6.

S9.4.1.1 *Operating instructions.* Each semiautomatic headlamp switching device must include operating instruction to permit a driver to operate the device correctly including; how to turn the automatic control on and off, how to adjust the provided sensitivity control, and any other specific instructions applicable to the particular device.

S9.4.1.2 *Manual override.* The device must include a means convenient to the driver for switching to the opposite beam from the one provided.

S9.4.1.3 *Fail safe operation.* A failure of the automatic control portion of the device must not result in the loss of manual operation of both upper and lower beams.

S9.4.1.4 *Automatic dimming indicator.* There must be a convenient means of informing the driver when the device is controlling the headlamps automatically. For systems certified to Option 1, the device shall not affect the function of the upper beam indicator light.

S9.4.1.5—*Option 1 (Semiautomatic Headlamp Beam Switching Devices)*

S9.4.1.5.1 *Lens accessibility.* The device lens must be accessible for cleaning when the device is installed on a vehicle.

S9.4.1.5.2 *Mounting height.* The center of the device lens must be mounted no less than 24 in. above the road surface.

S9.4.1.5.3 *Physical tests.* Each semiautomatic headlamp beam switching device must be designed to conform to all applicable performance requirements of S14.9.

S9.4.1.6—*Option 2 (Adaptive Driving Beam Systems).*

S9.4.1.6.1 The system must be capable of detecting system malfunctions (including but not limited to sensor obstruction).

S9.4.1.6.2 The system must notify the driver of a malfunction. If the ADB system detects a fault, it must disable the ADB system and the lighting system shall work in manual mode until the fault is corrected.

S9.4.1.6.3 The system must be designed to conform to the photometry requirements of Table XIX–d when tested according to the procedure of S14.9.3.12, and, for replaceable bulb headlighting systems, when using any replaceable light source designated for use in the system under test.

S9.4.1.6.4 When the system is producing an upper beam, the system must be designed to conform to the photometry requirements of Table XVIII as specified in Table II for the specific headlamp unit and aiming method, when tested according to the procedure of S14.2.5, and, for replaceable bulb headlighting systems, when using any replaceable light source designated for use in the system under test.

S9.4.1.6.5 For vehicle speeds below 25 mph, the system must produce a lower beam (unless overridden by the manual operator according to S9.4.1.1) designed to conform to the photometric intensity requires of Table XIX–a, XIX–b, or XIX–c as specified in Table II for the specific headlamp unit and aiming method, when tested according to the procedure of S14.2.5, and, for replaceable bulb headlighting systems, when using any replaceable light source designated for use in the system under test.

S9.4.1.6.6 When the system is producing a lower beam with an area of reduced light intensity designed to be directed towards oncoming or preceding vehicles, and an area of unreduced intensity in other directions, the system must be designed to conform to the photometric intensity requirements of Table XIX–a, XIX–b, or XIX–c as

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specified in Table II for the specific headlamp unit and aiming method, when tested according to the procedure of S14.2.5, and, for replaceable bulb headlighting systems, when using any replaceable light source designated for use in the system under test, within the area of reduced intensity.

S9.4.1.6.7 When the system is producing a lower beam with an area of reduced light intensity designed to be directed towards oncoming or preceding vehicles, and an area of unreduced intensity in other directions, the system must be designed to conform to the photometric intensity requirements of Table XVIII as specified in Table II for the specific headlamp unit and aiming method, when tested according to the procedure of S14.2.5, and, for replaceable bulb headlighting systems, when using any replaceable light source designated for use in the system under test, within the area of unreduced intensity.

S9.4.1.6.8 When the ADB system is activated, the lower beam may be provided by any combination of headlamps or light sources, provided there is a parking lamp. If parking lamps meeting the requirements of this standard are not installed, the ADB system may be provided using any combination of headlamps but must include the outermost installed headlamps to show the overall width of the vehicle.

* * * * *

S9.5 *Upper beam headlamp indicator.* Each vehicle must have a means for indicating to the driver when the upper beams of the headlighting system are activated. The upper beam headlamp indicator is not required to be activated when an Adaptive Driving Beam System is activated.

* * * * *

S14.9.3.12 *Test for compliance with adaptive driving beam photometry requirements.*

S14.9.3.12.1 *Stimulus Vehicles.* There shall be one stimulus vehicle equipped with photometers to measure the light emitted by the ADB-equipped vehicle being tested (test vehicle). The stimulus vehicle may be of any of the vehicle types defined in 49 CFR 571.3 (excluding trailers, motor-driven cycles, and low-speed vehicles) and shall be certified as conforming to all applicable FMVSS, be from any of the five model years prior to the model year of the test vehicle, and be a vehicle on which it is possible to locate a photometer to measure oncoming glare as specified in S14.9.3.12.3.

S14.9.3.12.2 *Photometers.*

S14.9.3.12.2.1 The photometer must be capable of a minimum measurement unit of 0.01 lux.

S14.9.3.12.2.2 The illuminance values from the photometers shall be collected at a rate of at least 200 Hz. Multiple photometers (or photometric receptor heads) may be used provided that they satisfy the requirements of S14.9.3.12.3.

S14.9.3.12.3 *Photometer Placement.* The photometers are placed in positions that are free from shadows and reflections from the stimulus vehicle's surface during the test.

S14.9.3.12.3.1 The photometer is oriented such that the plane in which the aperture of the meter resides is perpendicular to the longitudinal axis of the stimulus vehicle and facing forward or rearward according to the test.

S14.9.3.12.3.2 *Placement of photometers to measure glare to oncoming vehicles.*

S14.9.3.12.3.2.1 *Longitudinal position.* The photometer shall be positioned outside the vehicle, forward of the windshield and rearward of the headlamps.

S14.9.3.12.3.2.2 *Lateral position.* The photometer shall be positioned between and including the vehicle longitudinal centerline over to the driver's side A-pillar.

S14.9.3.12.3.2.3 *Vertical position.* The photometer shall be positioned between the bottom of the windshield and the top of the windshield subject to the lower and upper bounds specified in Table XXI.

S14.9.3.12.3.2.4 If it is not possible to so position the photometer, the vehicle is not eligible as a stimulus vehicle.

S14.9.3.12.3.3 *Placement of photometers to measure glare to preceding vehicles.* Photometers may be positioned at any location on the driver's side outside rearview mirror and/or the passenger's side outside rearview mirror, and/or outside the vehicle, directly outside the rear window, horizontally and vertically centered with respect to the inside rearview mirror.

S14.9.3.12.4 *Test road.*

S14.9.3.12.4.1 *Test Scenario Geometry.* Test scenarios shall involve straight roads and curved roads.

ADB TEST MATRIX

Test matrix No.	Stimulus vehicle speed (mph)	Test vehicle speed (mph)	Radius of curve (ft.)	Superelevation (%)
1	60–70	60–70	Straight	0–2
2	0	60–70	Straight	0–2
3	40–45	60–70	Straight	0–2
4	60–70	40–45	Straight	0–2
5	25–30	25–30	320–380	0–2
6	0	25–30	320–380	0–2
7	40–45	40–45	730–790	0–2
8	0	40–45	730–790	0–2
9	30–35	40–45	730–790	0–2
10	40–45	30–35	730–790	0–2
11	50–55	50–55	1,100–1,300	0–2
12	50–55	40–45	1,100–1,300	0–2
13	40–45	50–55	1,100–1,300	0–2

S14.9.3.12.4.2 The curves shall be of a constant radius within the range listed in the ADB test matrix table.

S14.9.3.12.4.3 The test road shall have a longitudinal grade (slope) that does not exceed 2%.

S14.9.3.12.4.4 The lane width shall be from 3.05 m (10 ft.) to 3.66 m (12 ft.)

S14.9.3.12.4.6 The lanes shall be adjacent, but may have a median of up to 6.1 m (20 ft.) wide, and shall not have any barrier taller than 0.3 m (12 in.) less than the mounting height of the stimulus vehicle's headlamps.

S14.9.3.12.4.7 The tests are conducted on a dry, uniform, solid-paved surface. The road surface shall

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have an International Roughness Index (IRI) of less than 1.5 m/km.

S14.9.3.12.4.8 The road surface may be concrete or asphalt, and shall not be bright white.

S14.9.3.12.4.9 The test road surface may have pavement markings, and shall be free of retroreflective material or elements that affect the outcome of the test.

S14.9.3.12.5 *Test Scenarios.*

S14.9.3.12.5.1 The scenarios specified in the table below, and as illustrated in Figures 23, 24, and 25, may be tested:

ADB Test Orientation

Direction	Lane orientation/maneuver	Test matrix No.	Measurement distance (m)
Oncoming	Adjacent	1, 2, 5, 6, 7, 8, 11	15 to 220.
Same Direction	Same Lane	1, 5, 7, 11	30 to 119.9.
Same Direction	Adjacent/Passing	2, 3, 6, 8, 9, 13	15 to 119.9.
Same Direction	Adjacent/Passing	4, 10, 12	30 to 119.9.

S14.9.3.12.5.2 For each of the test runs that include a passing maneuver, the faster vehicle will be located in the left adjacent lane throughout the test run (See Fig. 25).

S14.9.3.12.5.3 For each of the test runs that include a curve, the test vehicle must meet the compliance criteria specified in S14.9.3.12.8 anywhere along the curve.

S14.9.3.12.5.4 The measurement distance is the linear distance measured from the intersection of a horizontal plane through the headlamp light sources, a vertical plane through the headlamp light sources and a vertical plane through the vehicle's centerline to the forward most point of the relevant photometric receptor head mounted on the stimulus vehicle.

S14.9.3.12.6 *Test conditions.*

S14.9.3.12.6.1 Testing shall be conducted on dry pavement and with no precipitation.

S14.9.3.12.6.2 Testing shall be conducted only when the ambient illumination at the test road as recorded by the photometers is at or below 0.2 lux.

S14.9.3.12.7 *Test Procedures.*

S14.9.3.12.7.1 *Vehicle preparation.*

S14.9.3.12.7.1.1 Tires on the stimulus and the test vehicles are inflated to the manufacturer's recommended cold inflation pressure ±6895 pascal (1 psi). If more than one recommendation is provided, the tires are inflated to the lightly loaded condition.

S14.9.3.12.7.1.2 The fuel tanks of the stimulus and the test vehicles are filled to approximately 100% of capacity with the appropriate fuel and maintained to at least 75% percent capacity throughout the testing.

S14.9.3.12.7.1.3 Headlamps on the stimulus and test vehicles shall be aimed according to the manufacturer's instructions.

S14.9.3.12.7.1.4 The ADB system shall be adjusted according to the manufacturer's instructions.

S14.9.3.12.7.1.5 To the extent practicable, ADB sensors and the windshield on the test vehicle (if an ADB sensor is behind the windshield) shall be clean and free of dirt and debris.

S14.9.3.12.7.1.6 The headlamps lenses of the stimulus vehicle and the test vehicles shall be clean and free from dirt and debris.

S14.9.3.12.7.2 Prior to the start of each test, the photometers will be zeroed in the orientation (with respect to the surroundings) in which the test scenario will be conducted. For tests conducted on curves with ambient light sources such as the moon or infrastructure lighting that cannot be eliminated, the photometers will be zeroed in the direction of maximum ambient light. The vehicle lighting on the stimulus vehicle shall be in the same state as it will be during the test.

S14.9.3.12.7.3 The ADB system shall be activated according to the manufacturer's instructions.

S14.9.3.12.7.4 For each test run, a speed that conforms to the ADB test matrix table will be selected for each vehicle. The vehicle will achieve this speed ±0.45 m/s (1 mph) prior to reaching the data measurement distance specified in the ADB test orientation table and maintain it within the range specified in the test matrix table throughout the remainder of the test. During each test run, once the test speed is achieved and maintained, no sudden acceleration or braking shall occur.

S14.9.3.12.7.5 All vehicles shall be driven within the lane and will not change lanes during the data collection potion of the test.

S14.9.3.12.7.6 The illuminance values for each photometer and the measurement distance shall be recorded and synchronized.

S14.9.3.12.8 *Compliance Criteria.* The maximum illuminance, as calculated according to S14.9.3.12.8.1, shall not exceed the applicable maximum illuminance values in Table XIX–d.

S14.9.3.12.8.1 The maximum illuminance will be the single highest illuminance recorded within the distance range excluding momentary spikes above the limits lasting no longer than 0.1 sec. or over a distance range of no longer that 1 meter.

* * * * *

Table XIX–d—Adaptive Driving Beam Photometry Requirements [1]

Range (m)	Maximum illuminance oncoming direction (lux)	Maximum illuminance same direction (lux)
15.0 to 29.9	3.1	18.9
30.0 to 59.9	1.8	18.9
60 to 119.9	0.6	4.0
120 to 220	0.3	4.0

[1] For purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded to the nearest 0.1 lux, in accordance with the rounding method of ASTM Practice E29 Using Significant Digits in Test Data to Determine Conformance with Specifications.

* * * * *

Table XXI—Vertical Position Ranges for Photometer Used To Measure Oncoming Glare

Vehicle type (weight class)	Lower bound (m)	Upper bound (m)
Passenger Cars	1.07	1.15
Trucks, buses, MPVs (light)	1.26	1.58
Trucks, buses, MPVs (heavy)	1.99	2.67
Motorcycles	1.30	1.66

"Light" means vehicles with a GVWR of 10,000 lb. or less. "Heavy" means vehicles with a GVWR of more than 10,000 lb.

Heights are measured from the ground.

* * * * *

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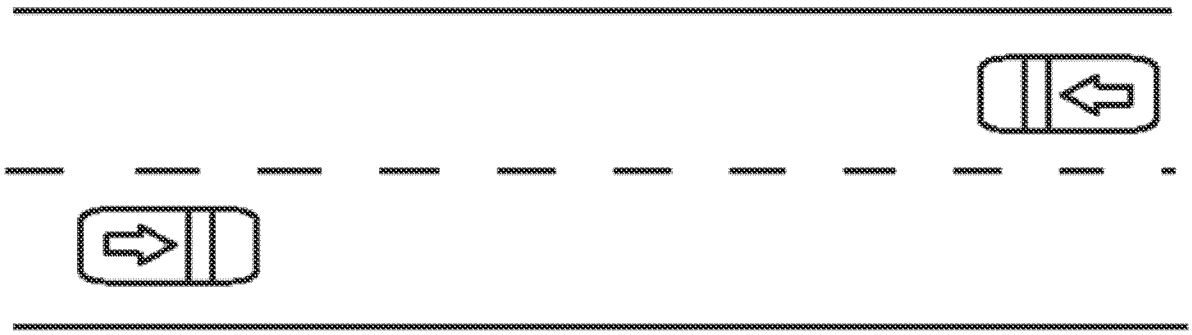


Figure 23

Adjacent Lane Oncoming

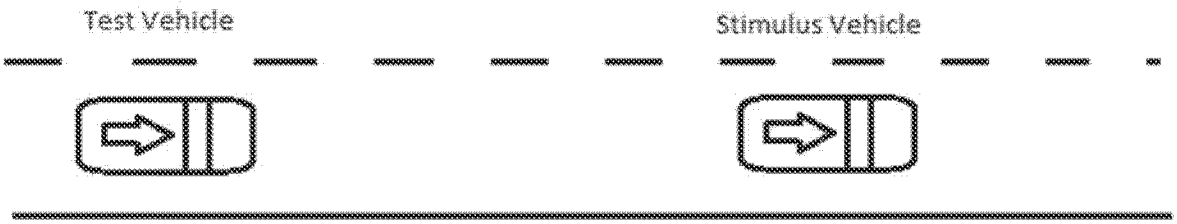


Figure 24

Same Lane / Same Direction

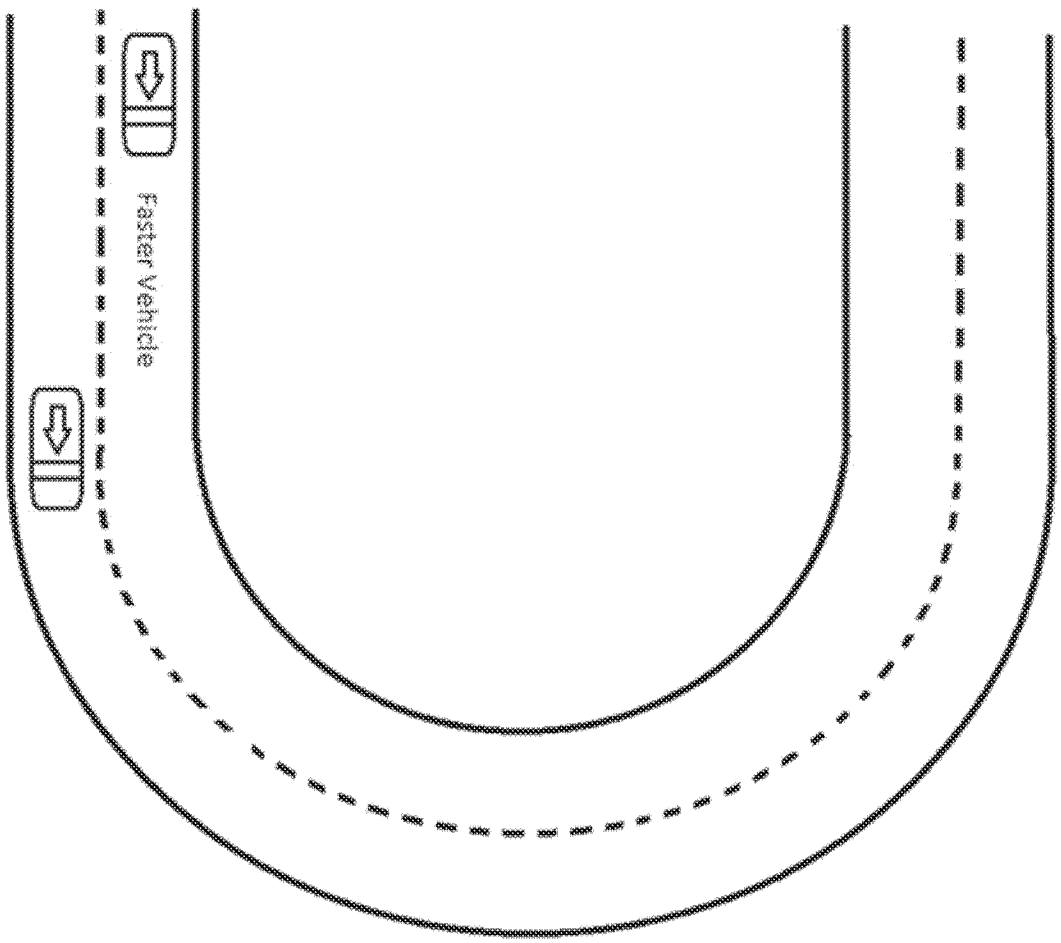


Figure 25

Adjacent Lane - Same Direction – Passing

Issued in Washington, DC, under authority delegated in 49 CFR 1.95 and 501.5.

Heidi Renate King,

Deputy Administrator.

[FR Doc. 2018–21853 Filed 10–11–18; 8:45 am]

BILLING CODE 4910–59–P

Exhibit 5
Koito Company History

Corporate Overview

Corporate Overview
- Corporate Profile
- Philosophy
- History of KOITO
  - Chronology
  - Milestone in 100 Years
- List of Business Points
- Executive Management
- Corporate Calender

Chronology

From Foundation to 1979's

1980's

1990's

2000's

2000	Jul.	Certified ISO14001.
	Aug.	Production and sales of High/Low Switchable Discharge Headlamps begin.
2001	Jan.	Certified QS-9000/ISO9001.
	Mar.	Koito Czech s.r.o. established. (Zatec, Czech Republic)
2002	Jul.	North American Lighting, Inc. Paris Plant opens. (Illinois, U.S.A.)
2003	Feb.	Production and sales of the world's first swivel AFS (Adaptive Front Lighting System) begins.
	Apr.	Production and sales of Discharge Bulbs begins.
2004	Jul.	Production and sales of the world's first Mercury-free Discharge Headlamps begins.
	Nov.	Koito Europe NV established. (Leuven, Belgium)
2005	Sep.	FUZHOU TAYIH INDUSTRIAL CO., LTD. becomes a KOITO subsidiary. (Fuzhou, China)
	Nov.	KOITO KYUSHU LIMITED established. (Saga, Japan)
	Nov.	GUANGZHOU KOITO AUTOMOTIVE LAMP CO., LTD. established. (Guangzhou, China)
2006	May	Certified ISO/TS16949.
	Jul.	Production of All Glass Sealed Beam Headlamps ends. (Production TTL: 430 million units)
	Oct.	KOITO KYUSHU LIMITED Plant opens. (Saga, Japan)
2007	Mar.	GUANGZHOU KOITO AUTOMOTIVE LAMP CO., LTD. Plant opens. (Guangzhou, China)
	May	Production and sales of the world's first LED Headlamps begins.
	Jul.	North American Lighting, Inc. Alabama Plant opens. (Alabama, U.S.A.)
	Sep.	INDIA JAPAN LIGHTING PRIVATE LIMITED [illegible]

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India)

2008 Feb. FUZHOU TAYIH INDUSTRIAL CO., LTD. becomes FUZHOU KOITO TAYIH AUTOMOTIVE LAMP CO., LTD.

Sep. KOITO KYUSHU LIMITED Second Plant opens. (Saga, Japan)

2010's

2020's

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Exhibit 6
HELLA Company History

HISTORY

2003
- Accelerator pedal sensor with accelerator pedal, is in a modular unit
- HELLA is the first company to produce cornering and dynamic bend lights in series
- The intelligent battery sensor (IBS) from HELLA delivers efficient energy management

2007
- The first front camera with traffic sign recognition

2008
- HELLA develops the first full LED headlamp for the Cadillac Escalade Platinum

2010
- First full LED headlamp with AFS functions for th Audi A8
- Dynamic Light Assist from HELLA enhances visibility

2012
- First Headlamp with LED Main Beam Function for the Truck Segment
- HELLA presents new workshop portal HELLA Tech World

● Company development ✓ Product development

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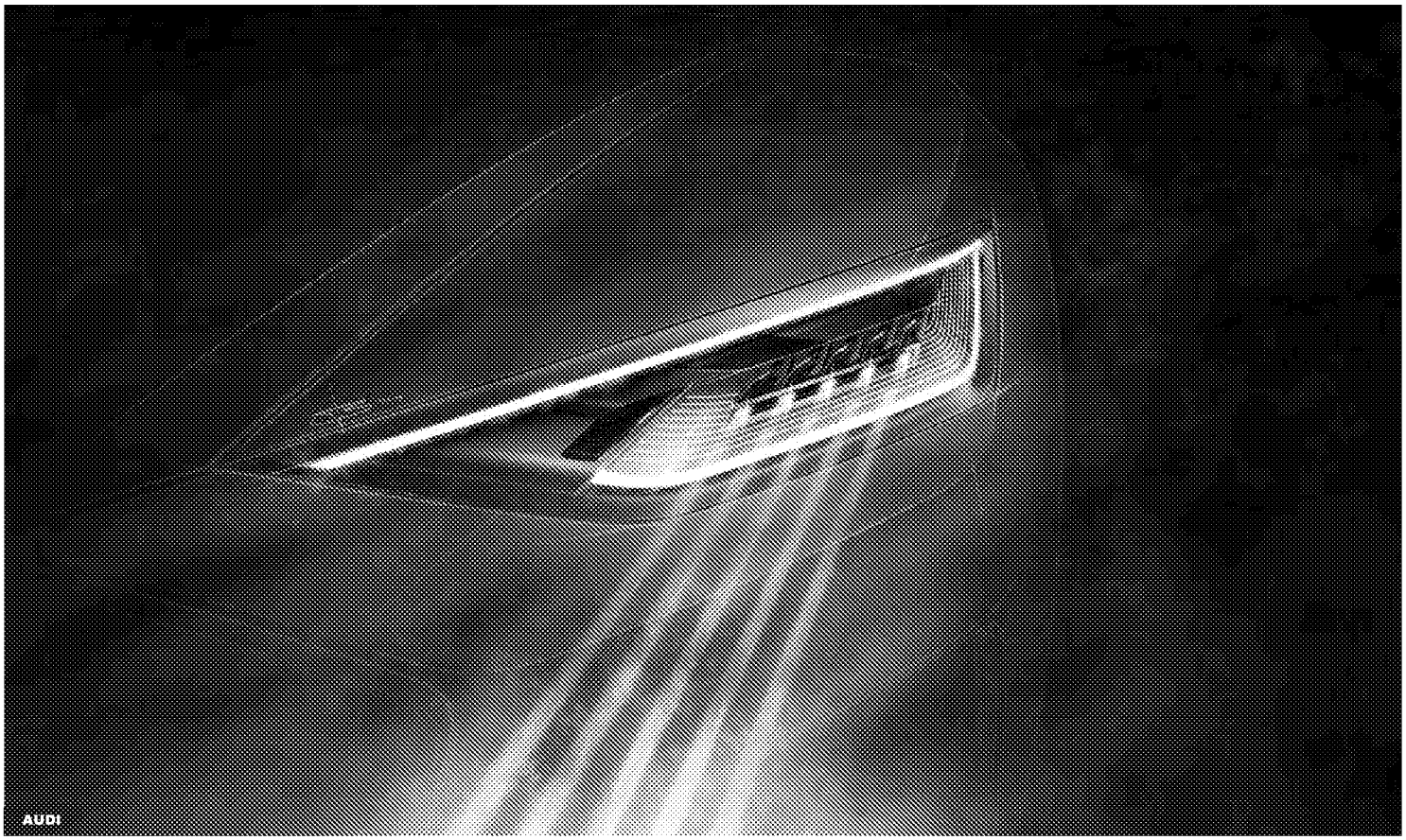
Exhibit 7
Autoweek April 2021

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Here's How Smart Headlights Work

This latest lighting tech makes the days of sealed beams look like the dark ages.

BY CHRIS TEAGUE APR 14, 2021



Automotive headlight designs have evolved considerably over the years, shifting from a utilitarian component of a vehicle to being a major part of its overall design and operation. In spite of that evolution, the basic functionality of most vehicles' lighting systems is the same as it was 50 years ago. Even fancy headlights are mostly limited in operation to low beams, high beams, and maybe the ability to automatically switch between the two depending on road conditions.

In some parts of the world, though, headlight designs are changing, and are doing so in a big way. They're becoming smarter and have been developed with the ability to shine differently in response to changes on (and near) the road ahead. The new

smart headlights make automatic high beams look like antique technology, so let's take a look at what they are and why they're so advanced.

What Are Smart Headlights?

Smart headlights, also known as adaptive headlights or adaptive driving beam headlights (ADB), illuminate the road with a constant beam that is as bright as a traditional headlight system's high beam. Rather than the driver or vehicle computer changing between two brightness settings, ADB systems use sensors and special light unit designs that can change the shape, brightness, and direction of the light. This can be done with a shutter system, which physically blocks part of the headlight beam, or with a matrix-style headlight unit made up of multiple light sources that can be turned on and off as needed. Adaptive headlights can also refer to light systems that shift direction depending on the vehicle's steering inputs, and you may hear the term being used to describe automatic high beam headlights or similar devices, but those systems are not functionally the same as the lights described here.

Provide Better Visibility and Less Distraction

Existing automatic high-beam headlight systems are great, but there are limitations to what they can do. If you're driving in a suburban area with traffic and streetlights, they can become confused and leave the bright beams on when they shouldn't, or in some cases they can end up switching between low and high beam lights rapidly, which is both annoying and bad for visibility. Smart headlights help alleviate these problems by reading the road and surrounding conditions and applying light only where it is needed. Instead of the need to switch between two brightness settings, adaptive headlights' brightness and shape change in response to surrounding conditions. Where some automatic high beam systems become confused between streetlights and oncoming headlights and switch off when they shouldn't, smart headlights' advanced sensors and detection systems will eliminate the errant shifts in brightness.

Safer in Poor Weather Conditions

If you've ever had to drive through a foggy, rainy night, you know the frustration of changing between low and high beam headlight settings, only to find that neither fits the situation quite right. Adaptive headlights won't fix everything in these scenarios, but they can illuminate the road ahead with much better accuracy and less reflection from heavy fog. ADB systems can change the shape of the light beam and some may incorporate fog lights into the mix as well, so they are able to direct the light lower and to the side of the road for better visibility without as much glare as traditional headlights.

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Doesn't Blind Others Nearby

It's no secret that the headlights on new cars are getting brighter. Now, even low beam headlights can be distracting to other drivers and pedestrians. Because adaptive headlights keep the bright lights off of pedestrians and other drivers, it's easier for people walking to stay out of the way and for other drivers to see where they're going. If there's an oncoming vehicle, the beam is partially blocked or turned off so that the other driver isn't blinded, but the rest of the road remains illuminated by bright light, which greatly improves their visibility without drastically reducing yours.

Are Smart Headlights Available in The United States?

Reading this, you'd think that adaptive headlights would be everywhere, but they're not available for drivers in the United States—at least yet. As *Car and Driver* reported in 2020, a rule developed way back in 1967 that set the definitions of low- and high-beam headlights is preventing the technology's forward progress. Automakers and many others have petitioned for an update to the rule, but as of April 2021, no changes have been made.

With or without the United States on board, ADB technology is moving forward quickly. Adaptive headlights will eventually be able to augment visual features of the road ahead, such as shining differently around a lane to help the driver stay on the road. Audi is one automaker pressing forward with the technology by developing systems that react to the driver's actions to better illuminate the road. The company

has presented examples which include a scenario where the lights dim out in the center of the lane and illuminate the sides of the road more brightly when approaching a large truck, a trick that essentially wraps light around the larger vehicle ahead and makes it easier to pass. At other times, the lighting system works in tandem with vehicle functions like navigation and head-up displays to highlight road signs and directions.

Even when adaptive headlight tech does make its way to the United States, it's likely to be considered a premium feature for some time. Advanced driver-assistance systems have only just begun trickling down into mainstream cars on a widespread basis in the past few years, but even now, features such as blind-spot monitoring and adaptive cruise control are often held back from standard-issue safety packages.

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Exhibit 9
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December 3, 2019

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Two Interesting New Lighting Systems From BMW

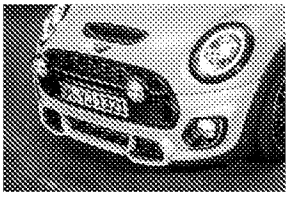
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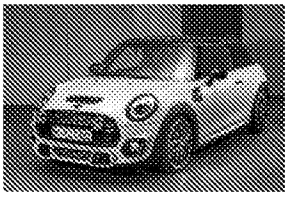


DVN had the chance last month to visit BMW in Munich, spending a fruitful time with Jörg Kälble, Rene Übler, and Johannes Aulbach. Before a night drive, Jörg organized a meeting in a brainstorming room with blackboards everywhere, very comfortable seats, and all provisions to be able to have relaxed conditions for creativity. We talked about BMW strategy on lighting, and on the feedback of BMW about the information received from DVN. A very fruitful time!

Then, two lighting systems were assessed in night drives: the Mini and the 5 Series equipped with ADB and laser.

Mini





Technologies involved in the Mini's lighting system

Full-LED Headlamps with glare-free high beam, done by a matrix 8i-LED module with eight matrix segments, four in each headlamp. The main goal of BMW here is to bring ADB functionality to the Mini customer. The benefit of a glare-free function is not only to shadow out other cars but also to provide further visibility for upcoming curves and dangerous situations; there is a clear safety gain by illuminating this curve in front of the driver.

Performance

Low beam flux: 800 lm
High beam flux: 1,800 lm
I_{max} = 93,750 cd

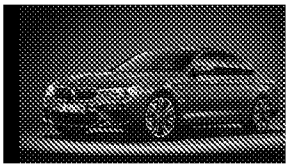
Lighting functions

Adaptive low beam distribution
Full high beam Glare-free high beam (called "Selective Beam" by BMW)Cornering lightStatic bending lightCity light

Night drive impressions

All the functions are useful.
• The low beam gives homogeneous luminance in the road and a good spread, like a carpet. Indeed, a pleasant light.
• The high beam is also homogeneous and a great quantity of light for this class of car.
• The ADB gives a feeling of a glare free high beam mainly when we have trees on the sides but has a low efficiency because the shadows are too large; they reduce the effect of good visibility at the immediate side of the car when you overtake or meet another car.
In conclusion, I have seen a very good light in low and high beam, maybe higher than we could expect from such a range. The number of segment is probably too low to have a good ADB.

BMW 5 Series



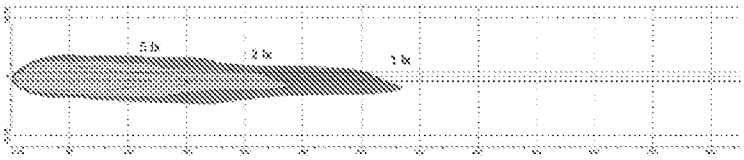
Technologies involved

This is the latest BMW laser headlamp, which combines a high-resolution glare-free high beam (0.1°) with a high range of visibility by activating the laser in full high beam as well as in glare-free high beam situations.

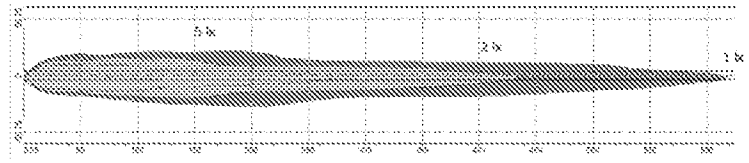
The laser high beam booster extends the seeing distance by nearly 300m. It's activated only if the car is exceeding 50 km/h.

Performance

Low beam flux: 1,000 lm
(Full) high beam flux: 3,800 lm
(Glare-free) high beam flux: 3,200 lm
Full high beam I_{max}: 200,000 cd
Glare-free high beam I_{max}: 175,000 cd
Glare free high beam resolution 0.1°
Because of the 175 kcd intensity in the glare-free high beam distribution we achieve up to 400 m seeing distance with resolution of 0.1° while driving in glare-free mode!



BMW 5 SERIES LED WITHOUT LASER BEAM



BMW 5 SERIES LED WITH LASER BEAM

Lighting functions

Adaptive low beam
Full high beam (including high beam laser boost)
Glare-free high beam (BMW "Selective Beam" including high beam laser boost)
Cornering Light
Adaptive bending Light
Predictive bending Light
Roundabout light
City Light

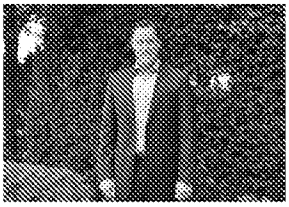
Night drive

In this car we have very efficient low and high beam, comparable with the best lights from Audi or Mercedes-Benz.
The ADB uses an interesting concept with a vertical cutoff just at the right side of the opposite car for the right headlamp, a vertical cutoff just at the left side of the opposite car for the left theadlamp, and a laser spot at the

SPERO EX. 2014

position of the vertical cutoff, able to have high level of light just at the right/left side of the car. So the quantity of light is quite great and the system is very efficient.

We took the opportunity to ask questions to Jörg Kälble. After studying mechanical engineering, Jörg Kälble started at BMW Motorrad in 1998 and was involved in the development of the new C1 scooter. From 2009 to 2013 he was group leader for the pre- and function development, simulation and protection of the exterior lighting on all models. After a 5-year excursion into quality work, in August 2018 he assumed overall responsibility for the exterior lighting development.



DVN: What is your feedback on the worldwide regulation process? Do you expect good progress with the strategic GTB committee?
J.K.:There is good coöperation in the GTB strategy team, and the initiatives on legislation proposed in connection with HAF have to be continued. New approaches need to be developed for cooperation with the Chinese regulatory authority.

DVN: How do you work with stylists? Are they the kings as in most automakers, or can you influence them?
J.K.: There is a continuous exchange between the designers and lighting designers, in which we show the technical possibilities and the designers represent their ideas. In that sense, I would like to call the coöperation good.

DVN: To make ADB, we have now different technologies including DMD, pLED, LCD, LCoS, laser scanning, and others. What is your vision with these technologies? Do you think one of them will come to dominate?
J.K.: All these techniques are interesting and have their advantages and disadvantages. In the end, the technology will prevail, which offers the customer a tangible added value and for which the customer is willing to pay the corresponding surcharge.

DVN: At ISAL, there were many lectures on road projections. How do you see road projection light in front of head-up displays?
J.K.: BMW has been offering HUD to the customer since 2003 and was thus for a long time the only European automaker to do so. Light projection is an interesting technique, but has against HUD the disadvantage that only at night there is a visibility. As such, light projection is a good way to support HUD functions (for example in hazardous situations) but will not replace them.

DVN: BMW presented at ISAL an interesting lecture on dynamic projection with welcoming light. Do you see a future with this function?
J.K.: The exterior lighting has a strong design character, the theme of light production is increasing--especially in Asia--in importance. I see the possibility that we can use functions like these in our cars at some point.

DVN : About the styling differentiation, BMW started with the innovative light rings, which have over the years evolved as a strong familial identifier. What do you think are the main axes of the DRL in the future?
J.K.: BMW was the first automaker who created a light icon with the "Angel Eyes" in the headlight. This can be found in advanced form to today in our cars and is a distinctive identifier. The customer will continue to recognise the BMW icon in the future, but of course we will continue to develop it further.

DVN : After one year at the head of lighting at BMW, what are your broad thoughts on headlamps and rear lamp systems?
J.K.: My vision is that the customer is optimally supported by our exterior light in every driving situation and he feels safe. The symbiosis of technology and design should make each BMW, Mini, and Rolls Royce unique and desirable, and surprise customers with BMW's innovative own ideas.

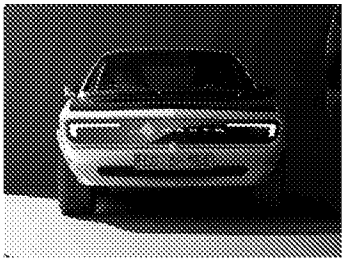
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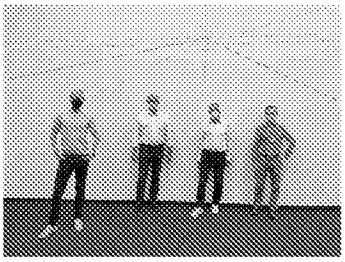
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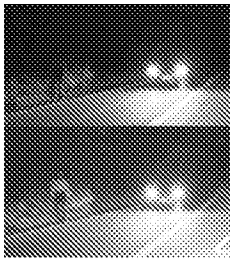
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PR Newswire
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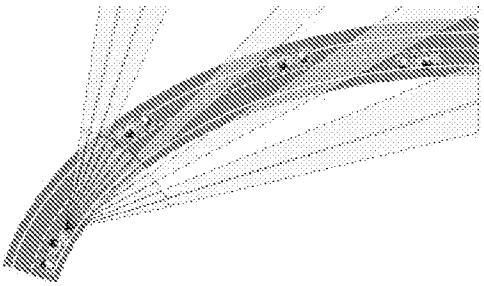
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HELLA's LED Matrix Lighting Wins Automotive News PACE Award

PR Newswire

PLYMOUTH, Mich., April 8, 2014

PLYMOUTH, Mich., April 8, 2014 /PRNewswire/ -- HELLA KGaA Hueck & Co., a global supplier of automotive lighting and electronic products, has won the prestigious 2014 *Automotive News* PACE Award for its industry-first adaptive LED Matrix Beam technology.



A leader in automotive lighting and electronics, HELLA's "glare-free high-beam" headlights use individually controlled LEDs that adjust automatically to real-time traffic conditions to reduce glare for other drivers.

The new Matrix Beam system combines a front camera, high-performance software and "intelligent lighting" technology to recognize cars that are being followed as well as oncoming traffic.

The system automatically adjusts a car's headlamps to deliver "glare free" illumination, dimming or switching on and off light sources based on traffic conditions. Individually controlled LEDs also provide two or more dark zones with "light in-between," allowing continuous use of a vehicle's high-beams to maximize visibility and provide a safer driving experience.

An industry first, HELLA's system utilizes 25 individually controlled LEDs arranged in a matrix format to provide car owners with an almost unlimited variety of lighting patterns. Audi became the first car company to introduce matrix lighting on its recently launched Audi A8.

LEDs are widely accepted in the industry as alternative light sources, supplying a variety of advantages when compared to traditional technologies such as halogen or xenon lighting. LED lighting imitates natural sunlight better than other light sources and can help reduce driver fatigue. It also can provide more "robust" solutions that don't depend on mechanical parts and are more durable than conventional lighting systems.

HELLA has participated in a number of previous PACE Award programs. In 2012, the company was recognized as a finalist for its Multi-Chip Module (MCM) oil sensing technology. Earlier nominations included full light-emitting diode (LED) headlamps in 2009 and an honorable mention in for its lane-change-assist technology in 2008.

HELLA was one of the 34 nominees for a 2014 PACE Award recognized in this year's award program.

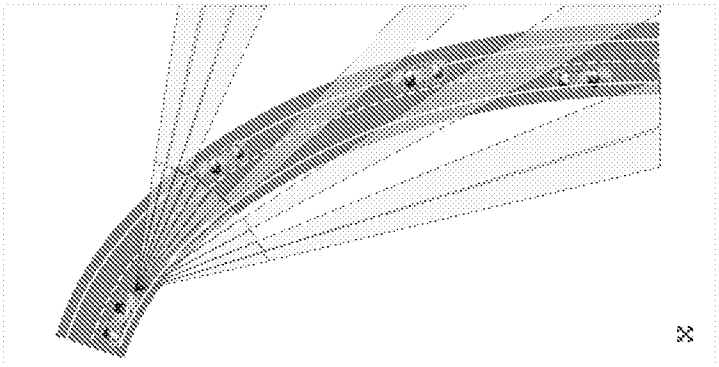
Note to Editors: Award photos are available on request.

About HELLA KGaA Hueck & Co.:

HELLA KGaA Hueck & Co. is a globally positioned, independent family-owned company with more than 30,000 employees at 100 locations in more than 35 countries. The HELLA Group develops and manufactures lighting and electronic components and systems for the automotive industry and also has one of the largest trade organizations for automotive parts, accessories, diagnosis and services within Europe. Complete vehicle modules, air-conditioning systems and vehicle electrical systems are produced in joint venture companies. With more than 5,500 people working in research and development, HELLA is one of the most important innovation drivers in the market. What's more, with sales of € 5.0 billion in fiscal year 2012/2013, the HELLA Group is one of the top 50 automotive parts suppliers in the world and one of the 100 largest German industrial companies.

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Matrix LED Light Patterns. (PRNewsFoto/HELLA KGaA Hueck & Co.)
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Exhibit 11
Alliance for Automotive Innovation Comment Submission July 31, 2020

ALLIANCE FOR AUTOMOTIVE INNOVATION

SUBMITTED ELECTRONICALLY VIA REGULATIONS.GOV

Mr. James Owens
Deputy Administrator
National Highway Traffic Safety Administration
1200 New Jersey Avenue S.E., West Building Washington D.C. 20590-0001

July 31, 2020

Re: NHTSA Notice of Proposed Rulemaking to Amend FMVSS No. 108 to Permit Adaptive Driving Beams, NHTSA Docket No. 2018-0090, 83 Fed. Reg. 51766 (October 12, 2018)

Dear Mr. Owens:

The Alliance for Automotive Innovation ("Auto Innovators") appreciates this opportunity to provide supplemental comments to the National Highway Traffic Safety Administration's ("NHTSA" or "Agency") notice of proposed rulemaking ("NPRM") for Federal Motor Vehicle Safety Standard ("FMVSS") 108, Lamps, Reflective Devices, and Associated Equipment, to permit the certification of Adaptive Driving Beam ("ADB") headlighting systems. Auto Innovators is the leading advocacy group for the auto industry, representing 37 innovative manufacturers and value chain partners who together produce nearly 99 percent of all light-duty vehicles sold in the United States.[1] The newly established organization, in part, a combination of the Association of Global Automakers and the Alliance of Automobile Manufacturers, is directly involved in regulatory and policy matters impacting the light-duty vehicle market across the country. Members include motor vehicle manufacturers, original equipment suppliers, technology and other automotive-related companies and trade associations.

Prior to the newly established organization, the Alliance of Automobile Manufacturers, in its December 2018 submission to the Agency, expressed intent to conduct testing to thoroughly assess the proposal's feasibility, and to inform future supplemental comments. Auto Innovators believed that simulating NHTSA's dynamic test procedure would provide information and data needed to competently address certain technical areas in the NPRM, and demonstrate concerns outlined in our previous comments. The test protocol, outlined in more detail below, was completed in late 2019. While our comments do not address NHTSA's proposed equipment-level laboratory testing requirements, we request that, should NHTSA conduct compliance testing, allowance be made for the contracted test laboratory to conduct

[1] The members of Auto Innovators include (alphabetically) Aptiv PLC, Aston Martin, Robert Bosch LLC, BMW Group, Byton, Cruise LLC, DENSO, Fiat Chrysler Automobiles, Ferrari S.p.A., Ford Motor Company, General Motors Company, Harman International, Honda Motor Company, Hyundai Motor America, Intel Corporation, Isuzu Motors Ltd., Jaguar Land Rover, Karma Automotive, Kia Motors, Local Motors, Maserati, Mazda Motor Corporation, McLaren Automotive, Mercedes-Benz USA, Mitsubishi Motors, Nissan Motor Company, NXP Semiconductors, Panasonic Corporation, Porsche, PSA North America, SiriusXM, Subaru, Suzuki, Texas Instruments, Toyota Motor Company, Volkswagen Group of America, and Volvo Car USA.

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calibration of any sensors required for ADB system performance prior to that testing, if requested by the vehicle manufacturer. Additionally, we wholly support the inclusion of a transition zone for equipment level laboratory testing as specified in SAE International Lighting System Group's comments[2] to the Agency in response to its NPRM.

We appreciate that NHTSA's proposal was developed with the intent that ADB systems operate safely by providing adequate visibility while mitigating glare upon other motorists. As a result of our testing, we have greater understanding of the Agency's proposed track test requirements and test procedures to evaluate ADB performance. Moreover, our assessment allowed us to develop meaningful feedback and recommendations to address both technical and feasibility concerns with the NPRM. Specifically, to improve practicability of the proposal, we recommend that NHTSA modifies certain portions of its test procedure to limit the number of test scenarios and scope of stimulus vehicles to evaluate ADB performance. We continue to emphasize from our prior comments that the variety (i.e., road geometry, vehicle speeds, and vehicle orientation) of scenarios selected by the Agency is excessive and unduly complicated to appropriately address the abilities of ADB systems.

The application of the Agency's derived glare limits is overly stringent and not based on modern headlight systems. NHTSA's application is also misguided towards preventing momentary discomfort glare at the expense of overall driver visibility. To incorporate more flexibility into the dynamic portions of the test protocol, while still ensuring that ADB systems increase visibility without introducing excessive glare, Auto Innovators recommends that the Agency consider an approach that relaxes the stringent glare limits for evaluating ADB performance, allows glare exceedance for more than one-tenth of a second, and provides required passage of a percentage of all test scenarios to achieve compliance. Other areas that we request the Agency's consideration include use of a static stimulus, standard stimulus lighting, and the allowance of horizontal aim. The rationale for each of these recommendations is presented in this comment submission.

Should the Agency foresee a final rule beyond the bounds set by 49 Code of Federal Regulations ("CFR") Part 555, we additionally encourage expeditious response to any outstanding petitions for temporary exemption of adaptive driving beam headlighting systems that it has received. BMW[3] and Volkswagen[4] have submitted petitions under 49 CFR Part 555 for their ADB systems in order to facilitate the field evaluation of these systems in the United States ("U.S."). We reiterate that ADB systems offer important safety benefits to the traveling public by incorporating the advantages of upper beams, thereby enhancing visibility, while avoiding their disadvantages by adjusting the light distribution and intensity to eliminate discomfort glare for other road users. We strongly support these petitions, and encourage the Agency to expedite their approval, in addition to any subsequent petitions NHTSA may receive from our members and other vehicle manufacturers.

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[2] *See* NHTSA Docket No. 2018-0090-0167 (October 12, 2018).
[3] *See* 83 FR 12650 (Mar. 22, 2018).
[4] *See* NHTSA Docket No. NHTSA-2017-0018 (September 11, 2017).

I. Auto Innovators Execution of NHTSA's Proposed Test Protocol

Following an extensive search for test facilities capable and equipped to replicate the Agency's proposal as accurately and efficiently as possible, Auto Innovators selected FT Techno of America, LLC ("FTTA") as its third-party vendor to conduct testing to evaluate the dynamic portions of NHTSA's proposed test procedure for FMVSS 108. FTTA specializes in vehicle dynamics, active safety, and Insurance Institute for Highway Safety ("IIHS") headlamp evaluations with their proving grounds located in Fowlerville, Michigan ("FPG"). A summary of the test protocol, observations, and example results are provided in this section.

A. Adaptive Driving Beam Test Protocol

The scope of our test protocol was limited to four test vehicles and four stimulus vehicles. The test vehicles were comprised of a small passenger car, a midsize sedan, a midsize sport utility vehicle ("SUV") and a large SUV. The small passenger car and midsize sedan were equipped with headlamps designed to the United Nations Economic Commission for Europe ("UNECE") R123[5] ADB requirements, the midsize SUV to SAE J3069™ but otherwise fully FMVSS 108 compliant, and the large SUV was fully FMVSS 108 compliant and then modified to mimic the UNECE R123 ADB function. For each test vehicle, tire pressures were set to vehicle specification and headlamp aims were unchanged from their received state or set to manufacturer specification. Stimulus vehicles were rented locally and selected according to the NPRM's Table XXI and S14.9.3.12.1, representing each vehicle type and from within five model years prior to the model year of the corresponding test vehicle. They were comprised of the following headlamp types: light-emitting diode ("LED") projector, LED reflector, halogen reflector and halogen projector, with their aim adjusted per manufacturer specification. Additional details for our stimulus vehicles can be found in Appendix A.

FTTA's equipment setup was similar to that described in the NPRM. FTTA utilized the same model illuminance (lux) sensors, high accuracy global positioning systems, vehicle-to-vehicle communication, and recording rate equipment (see Appendix B). Lux sensor count was limited to a critical number (e.g., driver forward, left rearview, right rearview, and center rearview when applicable). Data was collected by an acquisition unit aboard the stimulus vehicle, which in scenarios other than the motorcycle testing, was controlled by a passenger.

Unlike the NPRM, to measure lux sensor distance, FTTA utilized an optional multi-point live measurement feature of the OxTS equipment. The measurement was limited to 200 meters maximum, and most applicable for rear-facing sensors with critical measurements less than 120 meters. Forward-facing distance was determined with a live math channel resultant and offset from the Stimulus RT unit. In the NPRM, lux sensor distances were determined with a math offset post-test, in relation to true test

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[5] UN Regulation No. 123 – Uniform provisions concerning the approval of adaptive front-lighting systems (AFS) for motor vehicles.

measurement (between GPS antenna points). However, we believe that this change should not yield a difference in results.

FTTA determined that four lux sensors were adequate for this test, especially when placed in driver's glare zones. A center rearview sensor was not used for the heavy truck or motorcycle. On the light truck and passenger car, a center rearview sensor was positioned in line with the interior rearview mirror. All sensors were placed on the vehicle exterior to eliminate distortion or blockage potentially caused by glass.

Longitudinal lane international roughness index ("IRI") measurements remained within the NPRM's 1.5 meter per kilometer ("m/km") specification maximum, averaging near 0.475 m/km. Atypical IRI measurements across transverse lanes (east/west) are unknown and may have relevance for those test scenarios which include curves. Radius specifications and an overview of the test track layout can be found in Appendix C.

Modifications to curvature radii and superelevation specified in the NPRM were necessary to accommodate the track lengths at the FPG facility. In addition, changes were necessary to certain track geometries of the proposal to address safety concerns, specifically when testing mid radius preceding scenarios with the motorcycle stimulus vehicle at higher speeds. Similarly, FTTA operators also noted safety risks when conducting oncoming scenarios with each stimulus vehicle at speeds above 55 mph. FTTA also altered certain track and speed parameters from those proposed to account for differences in acceleration for each stimulus vehicle. This included adjusting two of three curve radii, along with three speed ranges, to conduct all test scenarios specified in the NPRM at the FPG facility. Had these adjustments not been made, distance requirements for certain test scenarios could not be met. Based on our experience, we believe that manufacturers will be unable to locate test facilities that are equipped to conduct all test scenarios proposed without modifications.

Approximately three to four hours were needed to complete testing for one vehicle set (i.e., one stimulus vs. one vehicle under test ("VUT")), with additional time needed for equipment validation and initialization. Although NHTSA did not address the number of test runs per scenario in the NPRM, Auto Innovators recommends an allowance of three or more runs for averaging and recognizing data anomalies. However, our testing was limited to two runs per scenario in the interest of total test time. Vehicles were refueled approximately half-way through the testing for each vehicle set to maintain above seventy-five percent fuel capacity. Synching path distance and speed timing were done by trial and error, with constant communication and feedback between vehicle operators. The stimulus vehicle maintained a second operator for real-time data verification of speeds, distance ranges, and equipment errors. For motorcycle testing, an operator rode in the VUT, conducting the same verifications through remote connection.

Lane position efforts were made by operators, despite a large tolerance when considering the 10'-12' maximum lane width for two lanes and two vehicles. Further, instances of roll angle and resulting lamp height variation were likely introduced while adjusting to maintain lane position.

B. Test Observations

Figure 1 below shows each test scenario and the corresponding speeds for the stimulus and VUT as outlined in the NPRM. This data also indicates the modifications made to test speeds and curve radii in certain scenarios. The curve radii specified in the NPRM were classified into three categories: small, mid, and large. In the mid radius scenario, with an actual 815'R curve, limited track length at the FPG facility necessitated modifications. Certain cases of slower paired vehicles showed difficulty reaching and maintaining specified speed in the finite length of the 815'R curve. When selecting the highest allowable delta between vehicles, it was still necessary to modify some speeds for length of test track within a curve.

The oncoming scenarios required adjustment for slower accelerating vehicles (i.e., no run-up on one curve end). In preceding scenarios, different speeds were needed to close or fill gaps to satisfy required test track lengths. In the large radius "preceding (same lane)" scenario, with an actual 1015'R curve, adjustment was also needed to meet the NPRM's requisite test track length.

		Oncoming			Preceding (Same Lane)			Preceding (VUT Passing on Left)			Preceding (Stimulus Passing on Left)			
		15-220m			30-119.9m			15-119.9m			30-119.9m			
		#	Stimulus	VUT	#	Stimulus	VUT	#	Stimulus	VUT	#	Stimulus	VUT	
Road D (Actual 1015'R)	Large Radius (1100-1300') RIGHT		50mph	50		50	60[1]							
												55	40	x2 runs = 8
									40	55				
	Large Radius (1100-1300') LEFT		50mph	50		50	60[1]							
												55	40	x2 runs = 8
									40	55				
Road C (Actual 815'R)	Mid Radius (730-790') RIGHT		45mph	45		30[2]	45							
			0	45					0	45				
									30	45				x2 runs = 12
												50[3]	25[4]	
	Mid Radius (730-790') LEFT		45mph	45		30[2]	45							
			0	45					0	45				
									30	45				x2 runs = 12
												50[3]	25[4]	
Road C (Actual 328'R)	Small Radius (320-380') RIGHT		30mph	30		25	30							
			0	30					0	30				x2 runs = 8
	Small Radius (320-380') LEFT		30mph	30		25	30							
			0	30					0	30				x2 runs = 8
Road D West Straight	Straightaway		70mph	70		60	70							
			0	70					0	70				
									40	70				x2 runs = 12
												70	40	

[1] Speed increased to from 55mph to 60mph. Original delta created difficulty catching stimulus in curve length.

[2] Speed decreased from 40mph to 30mph in order to cover test length.

[3] Speed Increased from 45mph to 50mph.

[4] Speed decreased from 30mph to 25mph. The oncoming scenario U-Haul stimulus was also reduced to 40mph.

Figure 1. ADB Headlight Test Matrix

C. Test Data

Figure 2 below shows an example of the data processing layout. The processing was done using a manual method of scroll bar channel overlays to find each maximum lux value. A formulated excel template or automated script could help expedite processing and ensure consistency.

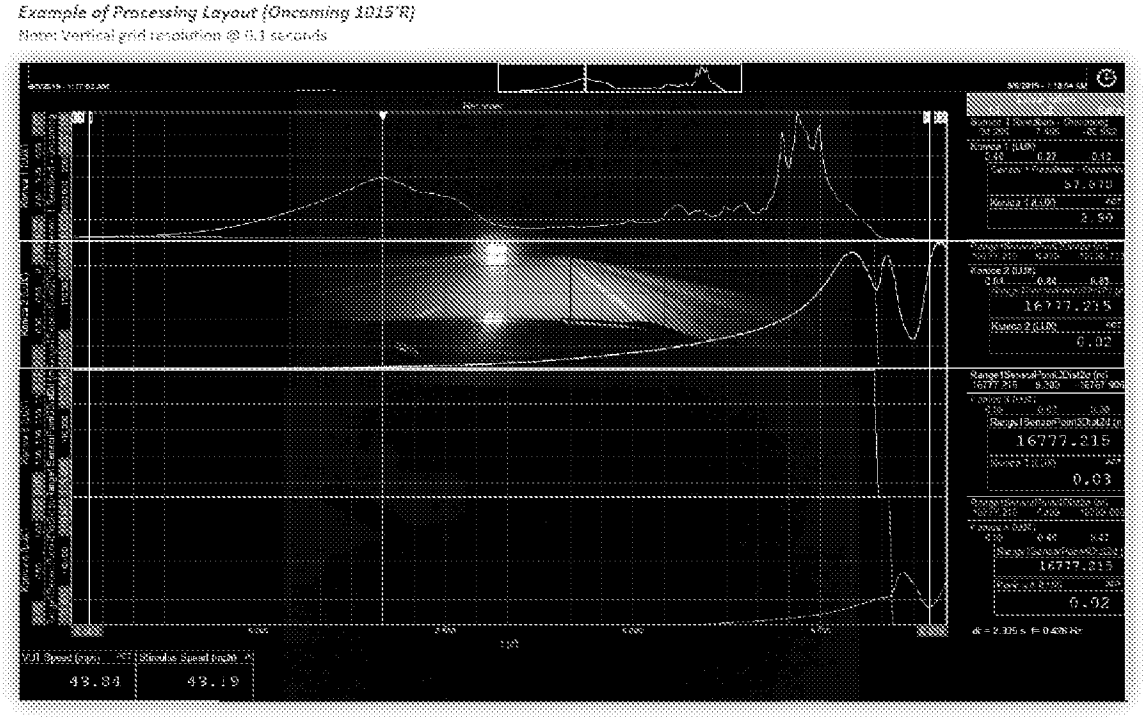


Figure 2. Example of Processing Layout (Oncoming 1015'R)

Figure 3 below shows an example of a data processing matrix. The final test results consist of Excel workbooks for each test vehicle. Each Excel workbook contains 16 tabs for the various stimulus vehicles and roadway geometries. The data contains values for peak lux along with the distance and speed of both the VUT and stimulus ("Stim") vehicle at peak lux. Speed values are shown in miles per hour (mph) and distance values in meters (m). If the lux value exceeded the NPRM glare limit, a value greater than zero is included under Glare Exceedance Time. Glare exceedance times greater than 0.1 seconds are highlighted in red. A cumulative value of all glare exceedance times in a given run is also included. In some cases, there were more than one glare exceedance per sensor and range, so multiple glare exceedance times are shown. Sensors or ranges that were not applicable are grayed out in the data processing matrix.

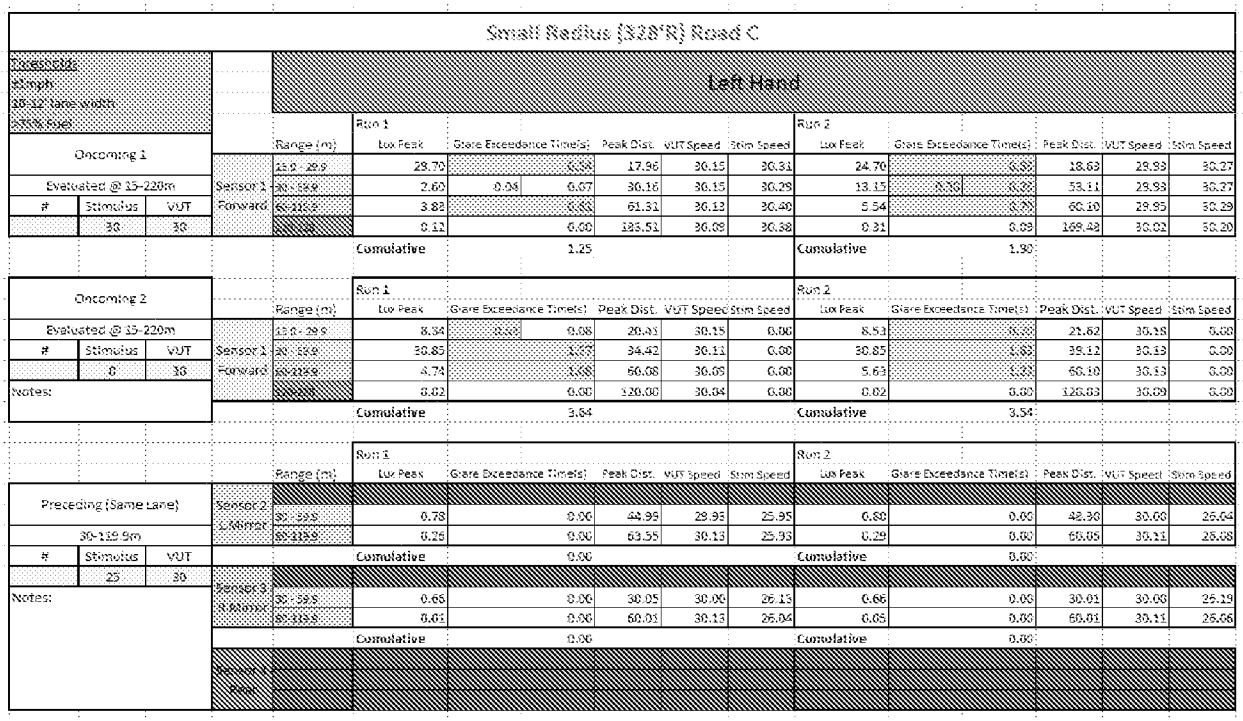


Figure 3. Example of Data Processing Matrix from the Small Passenger Car and Motorcycle on Small Radius, Left Hand Curve.

II. Glare, Visibility, and Pedestrian Safety

In its proposed amendment, NHTSA largely focuses on glare. The Agency notes that it is particularly concerned about ensuring, to a reasonable degree, that ADB systems do not glare other motorists, as glare is a negative externality that might not be sufficiently mitigated by market forces alone.[6] While we understand that discomfort glare is a concern for the Agency when evaluating ADB systems, we believe that this proposal minimizes the significant safety benefits of increased visibility that ADB brings, and its potential to reduce crash risk between vehicles and with pedestrians and other vulnerable road users. NHTSA's own research indicates that it is difficult to determine glare as a direct cause to crashes or fatalities.[7] While the Agency's evaluation has shown that an average of 0.3% of nighttime fatal crashes list glare as a contributing factor,[8] alternatively data shows that over 70% of pedestrian fatalities have occurred at night.[9] IIHS found that between 2009 and 2016, pedestrian deaths in dark conditions increased 56%.[10] The Government Accountability Office ("GAO") in its recent report cited that the number of pedestrians killed annually in motor vehicle crashes in the United States has

[6] NPRM at 51799.
[7] *See* Nighttime Glare and Driving Performance, Report to Congress, National Highway Traffic Safety Administration, Department of Transportation (2007).
[8] National Highway Traffic Safety Administration. 2014. Traffic Safety Facts 2012 Data: Pedestrians, DOT HS 811 888. Washington, DC: National Highway Traffic Safety Administration.
[9] National Highway Traffic Safety Administration. 2018 (Revised). Traffic Safety Facts 2016 Data: Pedestrians, DOT HS 812 493. Washington, DC: National Highway Traffic Safety Administration.
[10] https://www.iihs.org/iihs/sr/statusreport/article/53/3/1.

increased from about 4,400 in 2008 to almost 6,300 in 2018—a roughly 43 percent increase.[11] GAO recommended that NHTSA take additional action to address pedestrian safety.

While there are many factors that can be attributed to pedestrian fatalities and injuries, improved visibility benefits of ADB systems can help to decrease fatalities and injuries associated with these crashes. The increased illumination from ADB systems can contribute to considerably improving a driver's ability to identify obstacles or pedestrians on and off the roadway. Yet, NHTSA has chosen to focus more in this NPRM on discomfort glare rather than the safety benefits of ADB systems. We strongly encourage the Agency to not diminish the visibility improvements an ADB system can provide to disproportionately protect against discomfort glare.

A. IIHS Glare Limits

NHTSA proposes a set of glare limits from a 2011 University of Michigan Research Institute ("UMTRI") Feasibility Study ("Feasibility Study"), which is derived from reported median photometry of headlamps from 1997 model year U.S. vehicles.[12] Since 1997, headlight technologies that comply with FMVSS 108 have advanced drastically, including in the form of LED or high-intensity discharge ("HID") lighting that can provide greater levels of visibility without producing excessive glare. In addition to advancements in lighting hardware, in 2016 the IIHS introduced its Headlight Rating ("IIHS Headlight Rating") which has incentivized U.S. automakers to provide high levels of visibility without sacrificing glare performance.[13]

Regarding angle of incidence, the Feasibility Study rightfully notes that "[t]he disabling effects of glare (e.g., Vos, 2003) and the discomforting effects of glare (e.g., Schmidt-Clausen & Bindels, 1974) both fall off strongly as the angle between the glare source and the center of a person's field of view increase." The study notes that when separation distances between two vehicles are greater than 60 meters, glare illuminance values should be smaller; and when separation distances are shorter than 30 meters, glare illuminance values should be greater. However, the study is unable to compensate for these glare illuminance values because they "do not exactly fit the standard models of glare effects by angle."

As indicated in the rationale for the IIHS Headlight Rating, the IIHS takes a similar approach to the 2011 UMTRI Feasibility Study for establishing illuminance requirements.[14] In both studies, the illuminance of U.S. vehicle lower beam headlamp patterns compliant to FMVSS 108 are measured and extrapolated to establish illuminance criteria at different distances. However, the IIHS study departs

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[11] Government Accountability Office. (2020, April). *NHTSA Needs to Decide Whether to Include Pedestrian Safety Tests in Its New Car Assessment Program.* (Publication No. GAO-20-419). Retrieved from https://www.gao.gov/assets/710/706348.pdf.

[12] Michael J. Flannagan & John M. Sullivan. 2011. Feasibility of New Approaches for the Regulation of Motor Vehicle Lighting Performance. Washington, DC: National Highway Traffic Safety Administration.

[13] Insurance Institute for Highway Safety. (2018, July). *Headlight Test and Rating Protocol (Version III).*

[14] Insurance Institute for Highway Safety. (2015, August). *Rationale and Supporting Work for Headlight Test and Rating Protocol.*

from the Feasibility Study in three significant ways. First, the Feasibility Study uses "lamps typical of the 1997 model year", whereas the IIHS study uses lamps that are representative of headlamps on U.S. roads today.[15] Figures 4 and 5 below demonstrate the respective difference between the lower beam headlamp patterns used in the Feasibility Study and the IIHS study. Second, the IIHS study accounts for prior research that indicates that glare effects should consider both peak illuminance and overall "dosage" of glare exposure. This is the basis for the IIHS glare threshold that assesses illuminance in terms of overall exposure distance.

Third, the IIHS study accounts for glare effects due to incidence angle whereas the Feasibility Study does not. This is the basis for allowing 10 lux of glare illuminance for all approaches at distances between 5 and 10 meters, noting that "[a]t these smaller distances, drivers are less likely to be focused on the oncoming vehicle headlamps, and greater angular distances from the light sources are associated with less discomfort glare (Schmidt-Clausen and Bindels 1974)." Our test data shows that the least amount of failures occurred at the 15-29.9 meter distance range for both the oncoming and preceding scenarios. Additionally, the glare exceedance times for all the test failures in this range were 1.0 seconds or less. Based on these results, we believe that it is less critical to test the performance of ADB systems at this distance range. Accordingly, Auto Innovators recommends that NHTSA eliminate the 15-29.9 meter distance requirement for each oncoming and preceding test scenario.

From a technical design perspective, ADB systems that utilize a swiveling beam (as opposed to a matrix-style LED array) and that dip to a lower beam in the presence of other vehicles, operate by swiveling the dipped beam as far as possible outboard during passing scenarios at short distances. For example, as a stimulus vehicle passes an ADB vehicle on its left side, the ADB left hand lamp swivels, reaching its maximum swivel angle and the stimulus vehicle passes through the full lower beam pattern at the extremes. Due to the "kink" in the lower beam pattern necessitated under FMVSS 108 requirements, this creates an area of higher intensity light just to the right of the H-V point (see Figures below) that must pass over the stimulus vehicle as the ADB vehicle returns the swiveling lamp to center. This increased area of intensity may explain some of the exceedances at short distances in NHTSA's previous testing and similarly within the FTTA data. While this explanation is only relevant for swiveling beam ADB systems, Auto Innovators believes that any safety standard should remain

[15] Prior to the allowance of visual/optical headlamp aim, which was generally effective for the 1999 model year, including those used in the UMTRI study, headlamps were aimed by use of external mechanical aimers or by vehicle headlamp aiming devices (VHADs). Generally, all headlamps installed as original equipment on current light vehicles use visual/optical aim, and incorporate the characteristic sharp optical gradient used in visual/optical aim.

technology neutral. Also, the increased intensity resulting from any such situation would not functionally differ from any vehicle with traditional lower beams with a vehicle passing on its left side.

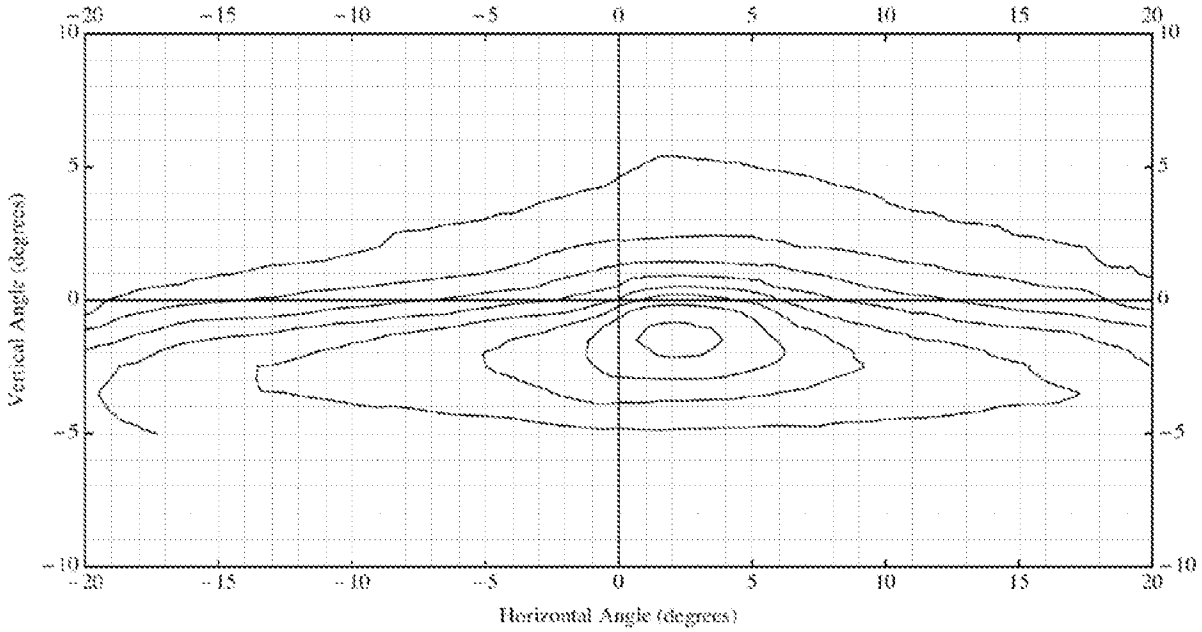


Figure 4. Low-Beam Headlamp Intensity Pattern from NHTSA Feasibility Study

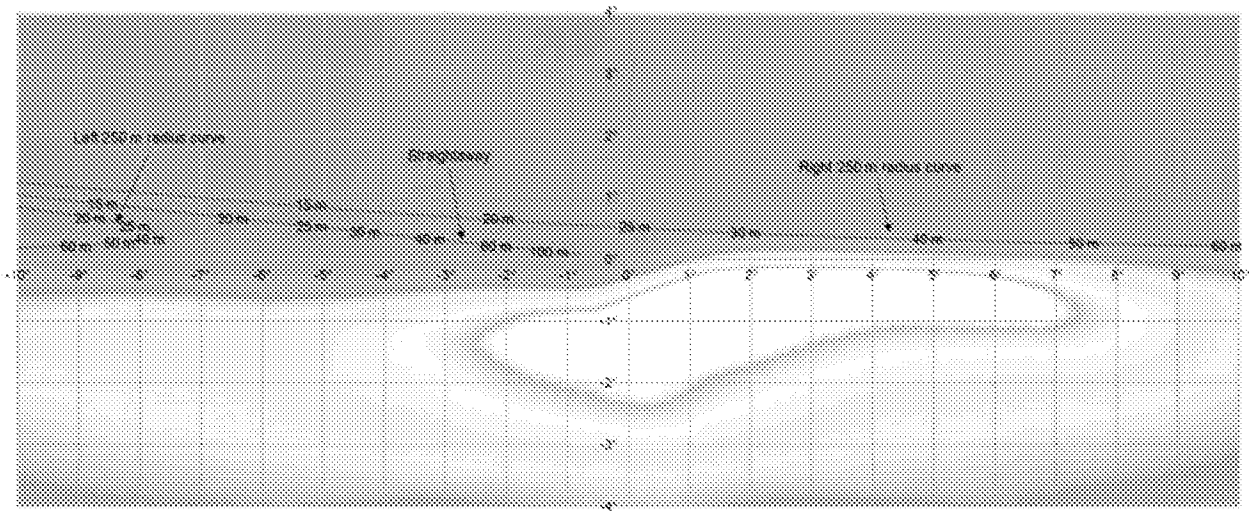


Figure 5. Low-Beam Headlight Intensity Pattern from IIHS Headlight Rating

Additionally, IIHS has studied headlamp performance and real world implications in order to add headlamp performance ratings into their test protocols and overall safety rating scheme. IIHS found that, "The lower beams of many headlight systems with poor ratings don't provide enough light for a driver going 55 mph on a straight road to stop in time after spotting an obstacle in his or her lane. They

provide even less illumination on the left side of a straight road and when driving on a curve."[16] IIHS indicates that upper beams are underused and that the use of high beam assist or ADB could increase the use of upper beams, thus improving visibility. The IIHS test protocol accounts for both visibility and glare. It attempts to limit discomfort glare, while not imposing disabling glare, underscoring NHTSA's focus on glare to road users.

B. IIHS Top Safety Pick Criteria

The IIHS Top Safety Pick criteria for headlamps has driven the industry to the current state of the art in increasing the need for visibility with simultaneous reductions in glare. IIHS "GOOD" rated headlamps serve to influence consumers' purchasing decisions through these ratings. When comparing the glare results of the model year ("MY") 2020 Top Safety Pick Plus ("TSP+") award winners having GOOD rated headlamps to the glare limit values provided in the present NPRM, it is clear that the glare limit values for ADB lamps are unreasonably stringent. The graph below presents the glare illuminance values from each of the 32 GOOD rated headlamps, and subsequent TSP+ vehicles, which are overlaid with the glare illuminance limits cited in the NPRM.

As evidenced in Figure 6, nine of the 32 GOOD rated headlamps (~28%) in the *low beam* configuration would fail the oncoming glare limits provided for in the NPRM. Because the highest IIHS rated lower beam headlamps would struggle to even meet the glare criteria requirements to which ADB lighting is being held, Auto Innovators believes that a relaxation of the glare limit values is appropriate. To align with IIHS consumer messaging for what constitutes a "good" headlamp, we recommend also aligning closer to the glare limits specified in the IIHS Headlight Evaluation.

[16] https://www.iihs.org/topics/headlights#headlight-performance.

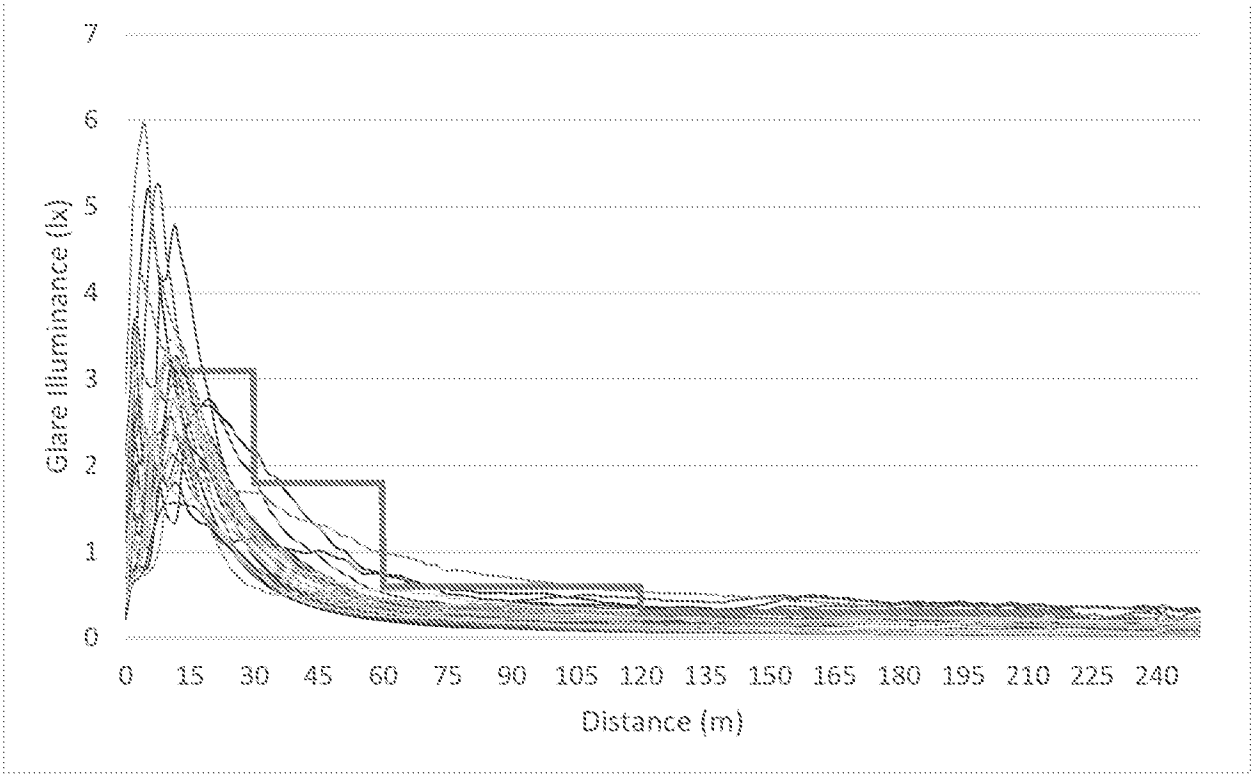


Figure 6. Glare illuminance versus distance of 32 IIHS GOOD rated MY2020 vehicles (blue) overlaid with NHTSA ADB NPRM glare limit values (red)

C. NHTSA Should Adopt IIHS Glare Limits

Auto Innovators believes that the glare limits presented in the IIHS test protocol, which examines visibility and glare from a real world perspective, reflect the performance bar set by modern headlights more accurately than the overly restrictive limits proposed in the NPRM. We recommend that the Agency adopts the glare limits utilized in the IIHS Headlight Evaluation as outlined below.

While IIHS provides glare exposure criteria for both a right curve and a straight/left curve scenario, we believe the right curve glare limits are more appropriate for application to the present rulemaking for all oncoming scenarios. Specifically, IIHS allows exceedances in the form of cumulative exposures as opposed to hard pass/fail limits. These cumulative glare exceedances result in a series of demerits for which it is possible for a vehicle to achieve a GOOD rating while still offering small amounts of glare. Auto Innovators recommends that the Agency adopts a similar method for establishing an allowable time exceedance for each test range. The IIHS model uses the percentage over the limit to determine glare demerits, an approach that should also be considered by NHTSA. We additionally note that the NPRM does not specify left or right curves, and request that NHTSA clarify whether which or both were contemplated for the ADB test procedure.

Secondly, the IIHS glare limits are intended to provide a relative assessment to consumers of headlamp performance rather than a strict compliance metric by which manufacturers will be held under this rulemaking. In other words, it is still possible for a vehicle to drastically exceed the glare criteria in the

IIHS test, earn a POOR rating, and still be fully FMVSS 108 compliant. For these reasons, we believe adopting the higher glare metric of the IIHS right curve scenario to apply to all oncoming scenarios offers sufficient balance between the need for limiting glare exposure while allowing for the benefits of ADB. Although IIHS provides a gradient of glare exposure limits, we recommend that NHTSA's proposed stepwise glare illuminance limits correlate to the IIHS curve at each step's shortest distance. Specifically, Auto Innovators offers the following modified glare limit criteria for the Agency's consideration:

Distance (m)	Lux Limit (lx)
30 to 59.9	6
60 to 119.9	3.4
120 to 220	1

Table 1. Modified Glare Limit Criteria Based on IIHS Glare Limits

III. Additional Recommendations to NHTSA

The recommendations that follow are substantiated by our ADB testing and data analysis. Auto Innovators believes that they will not diminish the Agency's objectives to develop performance requirements that demonstrate an ADB system is capable of providing increased visibility for the driver, while correctly detecting and mitigating glare to oncoming and preceding vehicles.

A. Modify Certain Portions of Test Procedure to Facilitate Practicability

1. Limit Dynamic Test Scenarios

The Agency states that the centerpiece of its proposal is a dynamic road test to evaluate the performance of ADB systems in a select number of driving scenarios and road configurations.[17] NHTSA selected a variety of different types of interactions with either an oncoming or preceding vehicle, different scenarios that vary the road geometry (straight or curved), vehicle speed (from 0 to 70 mph), and vehicle orientation. The Agency tentatively concluded that a dynamic road test was necessary to ensure that an ADB system meets minimum safety requirements for the prevention of glare. With respect to the track test, NHTSA's intent was to maintain a practical and efficient test while also reflecting real world conditions to which an ADB system would need to adapt to perform adequately.[18]

However, our experience simulating NHTSA's proposed scenarios did not amount to a practical nor efficient test. The rigor and specificity for the test tracks present not only the disparity to real world ADB performance, but also the challenge of vehicle self-certification and repeatable results. To further evaluate testing variability, one Auto Innovator member repeated a test series using a vehicle that was tested by FTTA and cited in the NPRM. The full test series was repeated under the same conditions using comparable measurement equipment. Despite careful attention to test setup and test conditions,

[17] NPRM at page 51767.
[18] NPRM at page 51781.

the results varied from those obtained by FTTA. The magnitude of the variation was sufficient to alter the compliance status of the vehicle.

Additionally, the number of tests and maneuvers in the NPRM require multiple sensor readings resulting in an extensive amount of data. The proposed track test includes 15 test modes and 34 tests per vehicle set. Each test has 3 or 4 sensor readings, resulting in 102 or 136 data elements per vehicle set. Testing four stimulus vehicles required analysis of 476 data elements. This is excessive and incompatible with many proving grounds, creating unassailable burdens for vehicle manufacturers. FTTA noted that it had underestimated the amount of time needed for data collection and processing. Test engineers used a manual method of scroll bar channel overlays to find the maximum lux value for each given range. As expected, this approach was very time consuming. Auto Innovators recommends that NHTSA develop software or other compliance tool to expedite processing the ADB test data. Overall, we conclude that the track testing proposed in the NPRM is overly complicated, not practicable, and does not reasonably address the abilities of ADB systems.

In consideration of the FTTA test results, Auto Innovators notes that certain test scenarios provided no additional benefit in determining whether an ADB system would provide undue glare to other road users. For example, the Preceding (Same Lane) test scenario resulted in only 5 failures out of 109 valid test runs (4.6%) across all stimulus and subject test vehicles. Therefore, we suggest that the Preceding (Same Lane) test scenario be eliminated because conformable performance in these scenarios will be accounted for by default. Further, Auto Innovators believes that by adopting the most stringent test scenarios at the extremes of the testing range, the intermediate tests will thereby be obviated. Measuring system performance at the extremes allows inference of system performance at points between those extremes. Specifically, the small radius curve was determined to be the most stringent test with 46 failures out of 127 valid test runs (36.2% failure rate). The failure rates for the straight, mid, and large radius test scenarios were 26.6%, 26.7%, and 22.4%, respectively. Therefore, by only requiring the straight and small radius test scenarios, an accurate assessment of overall system performance can be achieved.

Moreover, we recommend that NHTSA decrease the maximum test speed from 70 mph to 55mph. Since camera detection would be indifferent to the change in speed, we do not believe that testing to 70 mph is necessary to evaluate ADB performance. IIHS noted in its ADB testing rationale, that the majority of fatal nighttime passenger vehicle crashes on curves occur at speeds of 55 mph or less.[19] In addition, this change will help address safety concerns when testing on certain track geometries at higher speeds. High speed differentials pose an unreasonable safety risk for test operators, and certain vehicles such as the U-Haul (large truck), have difficulty reaching the specified test speeds in short times and/or distances allowed by a test facility. Limiting the test speed to 55 mph for all vehicles will still allow NHTSA to strike a reasonable balance between safety and practicability in its proposed test scenarios.

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[19] Insurance Institute for Highway Safety. (2015, August). *Rationale and Supporting Work for Headlight Test and Rating Protocol*.

Lastly, with regards to the stimulus vehicle selection, the test results showed that for all, but one valid test run for the light truck stimulus, each failure was mirrored by a failure with the Mustang stimulus for the same scenario. In other words, for all but one run using the light truck as the stimulus that exceeded the prescribed limits, a failure was also recorded for the same scenario using the Mustang as the stimulus. As the Mustang provided additional exceedance failures beyond the light truck, the Mustang clearly provided a more stringent stimulus. As the headlamp configurations for the Mustang (LED projectors) were similar to the light truck (HID projectors), i.e., similar color temperature, projector lens, and luminous intensity, the difference in performance is judged to be attributed to the geometries of both the headlamp mounting as well as the sensor mounting locations. As the bounds for the light truck presented in Table XXI are between the passenger car and the heavy truck, Auto Innovators believe that the need for an intermediate stimulus vehicle geometry is unwarranted along the same logic provided in the previous argument. Therefore, we recommend the elimination of the light truck as a required stimulus vehicle.

2. Allow a Static Stimulus in the ADB Test Procedure

A static stimulus can be used to represent preceding and opposing subject vehicles, such as a car, truck or a motorcycle as described in SAE J3069™.[20] The Agency decided not to use a static stimulus in this NPRM, citing its concern that a static stimulus is not realistic and may encourage ADB systems to be designed to ensure identification of a static stimulus rather than actual vehicles. To address NHTSA's concern, SAE International is considering a revision of its recommended practice to include that a static stimulus can appear like the vehicle it represents in 3-dimensions.[21]

The NPRM noted that a static stimulus has the advantage of relative simplicity and ease of testing. It also helps to reduce test variability, such as lateral variation, differences in vehicle speeds or changing ambient lighting. Ultimately, a static stimulus can enable repeatability while minimizing test burden. In addition, Auto Innovators' experience on the test track revealed potential safety issues with two vehicles driving at high speed in close proximity during nighttime test scenarios. A static stimulus, which would replace the subject stimulus vehicle, would help increase safety during testing.

Auto Innovators supports SAE International's position that a static stimulus is considered the most challenging scenario since some camera systems utilize opposing or preceding vehicles' movement within a scene to identify them as vehicles instead of other road objects, such as reflectors on the side of the road. We also support SAE International's position that a "standardized" stimulus lighting device, standard in illuminance, color and illuminated area, is intended to represent the minimum for each allowed in FMVSS 108. Since a static stimulus with minimum stimulus illuminance, color and illuminated area is the most challenging test scenario, it can be considered the worst case for the ADB system to differentiate a vehicle from other objects. Using static stimuli and/or standardized stimulus lighting devices not only provides each manufacturer with repeatable and objective criteria to which to test, but also affords the same to the Agency and/or to the third parties contracted to carryout compliance

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[20] SAE J3069™ (JUN 2016), pages 11-13.
[21] SAE International's proposed revision will be voted on in late Summer or Fall 2020.

testing on the Agency's behalf. For these reasons, we recommend that NHTSA reconsiders the use of a static stimulus, such as a static test fixture or actual vehicle, and/or standardized stimulus lighting devices in this NPRM.

Allowing standardized headlamps and tail lamps for the stimuli is an obvious mitigating tactic. Auto Innovators also points out that standardized lighting device stimuli need not be restricted to static evaluations, i.e., they could be mounted to vehicle 'mules' in various locations as needed, and tested dynamically. Either way, the approach is a more repeatable, objective, and orderly means for demonstrating compliance than the proposed use of publicly available vehicles.

Vehicle designs have certain variability, simply by the complexity of the product alone, but there are also the unfortunate instances where designs are found to later be not compliant, or not to design intent, forcing manufacturers to make in-cycle design changes or actions. These changes will not always be known at the time a manufacturer of the ADB vehicle conducts self-certification testing nor to a third-party conducting compliance testing for the Agency. Such changes will not amend model name, model year, trim series, or vehicle identification number. Auto Innovators believes this presents an unforeseeable incertitude to the compliance process with potential for chaos in the industry. If a stimulus vehicle used for compliance testing later conducted a recall on its headlighting or tail lighting, or even to a non-lighting component that affected its driving dynamics, pitch or ride height, and the remedy involved a change in design, what, if any, repercussions would there be for the ADB manufacturer and its already achieved compliance to the ADB requirements? Other potential unknowns for vehicles acquired 'in the field,' vehicles that will have been handled and driven by many prior to being used as a stimulus, are additionally disconcerting.

3. Limit Stimulus Vehicle Five Year Prior Model Year Requirement

The NPRM is unclear as to the number of stimulus vehicles that will be used in the Agency's evaluation of ADB systems, and how audit testing will be conducted. Auto Innovators requests that the Agency provide clarification on these issues. While we continue to view the static stimulus as the best path forward for practicably evaluating ADB systems under the most challenging scenarios, if the Agency moves forward with the usage of dynamic stimulus vehicles and intends that automakers should certify with stimulus vehicles in every classification, we urge the Agency to consider greater objectivity in this process. We propose that NHTSA limit the extensive list of proposed stimulus vehicles to a practical and manageable list which includes a specific stimulus vehicle from each of the following FMVSS classifications identified in Table XXI of the NPRM: passenger vehicle; light truck, bus, or multi-purpose passenger vehicle ("MPV")[22]; heavy truck, bus, or MPV; and motorcycle. We recognize that the proposal to limit the list to one stimulus vehicle from each of the classifications presents challenges with respect to the appropriate determination of which vehicle to utilize and may raise concerns that this

[22] In section II.A.1. above, we propose eliminating the light truck stimulus vehicle from the list of stimulus vehicles for testing.

process is subject to gaming. To address such concerns, we propose that the single stimulus vehicle from each vehicle classification shall be selected by the Agency, using a criteria that is transparent and self-executing, to the greatest extent possible.

We specifically recommend that the Agency select a single set of stimulus vehicles every 5 years, based on the best-selling make and model within each vehicle classification for a single model year. This stimulus vehicle set would remain in effect for 10 years, and be updated every 5 years. This means that after the initial 5 year period for the first set of stimulus vehicles, there would be two overlapping stimulus vehicle sets at any moment in time, and would continue ad infinitum. This overlap would provide regulatory certainty for variations in vehicle development lifecycles. To demonstrate this proposal, we offer the following example.

Assuming this rulemaking begins to allow compliance for 2021 MY ADB vehicles, the following set of stimulus vehicles would be selected from the prior 2020 model year based on the makes and models with the highest sales volume in each classification[23]:

- Passenger Cars: 2020 MY Toyota Camry
- Trucks, buses, MPVs (light): 2020 MY Ford F-150, should the agency not accept our suggestion to eliminate the light truck as a stimulus
- Trucks, buses, MPVs (heavy): 2020 MY Ford E-450
- Motorcycles: 2020 MY Harley-Davidson Iron 1200

This initial list of stimulus vehicles would be used for certifying the compliance of 2021 to 2030 MY ADB vehicles. Five years later at 2026 MY timing, the Agency would provide a second list, again based upon sales volume in each vehicle classification in the prior model year, in this case 2025 MY. This subsequent list of stimulus vehicles would be used for certifying 2026 to 2036 MY ADB vehicles, in addition to the previous list with an expiration of 2030 MY. This selection process would continue to repeat every 5 years. Because headlight and/or tail light designs can vary within a given vehicle make and model line, we propose that the Agency select a specific headlight and tail light design for the stimulus vehicles selected for the list.

We believe that this transparent self-executing update to the stimulus vehicle strikes an appropriate balance between burden and practicability, while also addressing concerns with gaming. This allows manufacturers and NHTSA test facilities to maintain a limited set of stimulus vehicles and conduct certification testing within a finite amount of time. The 10-year phase out also provides manufacturers with sufficient lead time and regulatory certainty that is needed at the beginning of any vehicle development cycle, and currently provided in other FMVSSs. With respect to gaming, we believe that this approach addresses potential concerns e.g., lack of accounting for stimulus vehicles that may have a

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[23] In light of the current production impact due to COVID-19, and general potential for sales fluctuation due to model lineup changes, we further recommend that the Agency consider aggregating the sales volume for the prior 5 model years, and not necessarily just the prior model year. In the case of the example, these 2020 MY vehicles could also be selected based on combined sales volume leaders during the entire period of 2016 to 2020 MY.

unique headlamp design, lack of incentivization to manufacturers to test for a variety of stimulus vehicles, or that this requirement does not cover the entire range of possible stimulus vehicles in several ways. First, the selection of these stimulus vehicles is completely out of the control of the manufacturers. This unbiased selection process requires that manufacturers ensure that ADB systems recognize actual vehicle headlamp types on our roads today, and continue to do so as headlamps systems evolve. Second, this approach indeed requires that ADB systems recognize a wide variety of stimulus vehicles by maintaining the proposed requirement to certify against a variety of stimulus vehicle classifications. Third, the selection of the stimulus vehicle based on greatest total sales volume ensures that the selected headlight and tail light stimuli are the most appropriate representation possible within each classification. To reiterate, if it is the Agency's intent that automakers should certify with stimulus vehicles in every classification, we request consideration be made for this alternate proposal.

We agree with NHTSA that an ADB system should be able to identify a wide range of different vehicle types, just as camera-based auto high beam ("AHB") systems (i.e., semiautomatic headlamp beam switching devices) have been doing since 2004. We estimate more than seventeen million vehicles, greater than 50% of some automakers' sales, are equipped with camera-controlled AHB systems. These systems currently use similar or identical forward vision camera and vehicle identification algorithms as today's ADB systems in countries outside of the United States. Automobile manufacturer members of Auto Innovators agree that their AHB systems, which were designed without the type of rigorous examination laid out in the NPRM, have not resulted in increased discomfort glare complaints. This longstanding precedence should serve as an undoubting indicator that future ADB systems, using similar control hardware and algorithms, will provide superior visibility performance while protecting against discomfort glare, similar to AHB systems.[24]

Further, having an ADB system recognize any vehicle in every segment is a contrary approach compared to other FMVSS' test protocols which account for real world variations under objective and repeatable conditions. For example, FMVSS 208 accounts for the population of all possible drivers by testing with just 5th percentile female, 50th percentile male, and 95th percentile male crash test dummies. It additionally uses a NHTSA-defined fixed barrier,[25] one specified range of vehicle test speeds, and adjustments of components like seats, steering wheels, seat belt anchorages and head restraints are specified and limited.

The proposed requirement for selecting random stimulus vehicles from within the preceding five model years does not strike a reasonable balance between the need for safety and practicability. Other standards are based, in the case of FMVSS 208, on one crash "partner" intended to represent a much greater crash population, e.g., crash barrier, crash speed, anthropomorphic test device ("ATD"), surrogate subject vehicle ("SSV"), pedestrian dummy, etc. However, in this ADB NPRM, we are being asked to recognize every "partner", in every "partner" segment from the last five model years. Our proposal still allows for an ADB system to test to a broad range of stimulus vehicles that are

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[24] Michael J. Flannagan & John M. Sullivan. 2011. Preliminary Assessment of The Potential Benefits of Adaptive Driving Beams, UMTRI–2011–37. University of Michigan, Transportation Research Institute.
[25] Part 571 Subpart A General definitions.

representative of the current vehicle population, and to reiterate, will use similar operating parameters as AHB, a feature with proven precedence in the field. It is unnecessary to test practically every vehicle on the road to demonstrate compliance when vehicles within a category are substantially similar.

Checking representative vehicles through the track test and better defining those representative vehicles will make the standard practicable without limiting the safety benefits. Also, this approach addresses the Agency's concerns of whether glare prevention can be adequately ensured with a smaller set of stimulus vehicles, limits manufacturer burden in testing, and would encourage repeatability to compare ADB performance between tests.

B. Technical Recommendations

1. Require Passage of a Percentage of Individual Illuminance Readings to Achieve Compliance

Auto Innovators proposes a new approach for determining compliance to the Agency's proposed FMVSS 108 test procedures to evaluate ADB performance. Instead of requiring that an ADB system pass all the test scenarios outlined in the NPRM, we recommend that NHTSA instead require passage of a percentage of individual illuminance readings to achieve compliance. We believe that this approach may be supported by the design to conform provision included in the NPRM. The Agency has proposed to extend the design to conform language that has been part of FMVSS 108 since its inception to the proposed requirements for ADB.[26] With design to conform, NHTSA has stated that it will not consider a lamp to be noncompliant if its failure to meet a test point is random and occasional, and historically, there has never been an absolute requirement that every motor vehicle lighting device meet every single photometric test point to comply with FMVSS 108.[27]

The NPRM includes 34 individual test scenarios with three or four illuminance readings taken for each test for a total of 102 or 136 illuminance readings for a full compliance test for each ADB-equipped vehicle.[28] It would be helpful if the Agency provided guidance as to how the "occasional and random" criteria would apply, since the readings in the proposed ADB test represent the maximum value recorded over a period of time rather than readings historically taken in FMVSS 108 that are at points, along lines, or in zones in a defined two dimensional grid. Since its inception, all photometric testing conducted according to FMVSS 108 has been with the lighting device and the photodetector having a static physical relationship between them. However, the large majority of NHTSA's proposed ADB tests would occur with continuous movement between the device being tested and the photodetector—often time with the relative movement occurring in three planes.

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[26] NPRM at 51786.
[27] *Id.*
[28] FMVSS 108 photometric test requirements include at most 4 individual readings for upper beam headlamp maximum intensity, and 10 individual readings for lower beam headlamp maximum intensity.

Additionally, unlike photometry conducted in dedicated indoor test facilities where the temperature, humidity, and ambient lighting can be strictly controlled, outdoor test conditions cannot be controlled.[29] It would be difficult not to attribute failures of illuminance readings to variances that could appear in the novel and unique aspects of the test procedure, rather than to quality control issues particularly where the time and complexity of the testing preclude conducting it on multiple ADB-equipped vehicles.[30] To further account for the test variations associated with this type of testing, we propose that up to three test runs for each individual test scenario be permitted, and an average of the individual illuminance readings for those runs be used as the reported maximum illuminance reading for that test scenario.

We believe that an appropriate basis for compliance for ADB systems should allow up to 15% of the individual illuminance readings to exceed the glare limits proposed in our comments by no more than 25% in intensity. The precedence for allowing exceeding glare limits by no more than 25% in intensity is described below, while the allowance for up to 15% in quantity comes from FMVSS 108 itself. S14.9.3 of FMVSS 108 requires that 20 flashers chosen from a lot of 50 be subject to a starting time test, a voltage drop test, a flash rate and percent current "on" time test, and a durability test where the performance requirements for these two devices are considered to have been met if 17 of the 20 samples (85%) comply. This amount of performance variation would seem consistent with the previously noted challenges of outdoor dynamic testing where little previous experience exists.

The concept that slight differences in light intensity are generally not perceivable to human observers has been widely supported in various studies including those by NHTSA[31] and UMTRI.[32] These studies have interpreted such slight differences to not exceed 25%. The Agency, in granting an inconsequential noncompliance petition from Hella, confirmed that the 25% criteria applied to situations where the actual lamp intensity was above the stated requirement maximum.[33] Also, NHTSA recently used a similar basis to grant petitions for inconsequential noncompliance from Nissan and Toyota.[34] Auto Innovators recommends that NHTSA consider evaluating whether its test procedure for ADB should allow for compliance of a percentage of all test scenarios based on the Agency's provision of design to conform in FMVSS 108.

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[29] Although the IIHS states that, "a full moon on a cloudless night illuminates the ground below to about 1 lux", its headlight test and rating protocol limits tests to where the ambient light is below 0.3 lux. Insurance Institute for Highway Safety. (2018, July). *Headlight Test and Rating Protocol (Version III)*.

[30] NHTSA conducted testing of several ECE compliant vehicles equipped with ADB using modified ECE R48 and R123 vehicle tests. The Agency concluded that, *"Multiple test trials per scenario would serve to compensate for variability in dynamic maneuver scenario performance as well as ADB performance variability. More than three trials per scenario are recommended.* DOT HS 812 174 August 2015, Page 18.

[31] *Driver Perception of Just Noticeable Difference(s) in Signal Lamp Intensities*, DOT HS 808 209, September 1994.

[32] Sayer, J. R., Flannagan, M. J., Sivak, M., Kojima, S., & Flannagan, C. C. (1997). Just Noticeable Differences for Low-Beam Headlamp Intensities (Report No. UMTRI-97-4). Ann Arbor: The University of Michigan Transportation Research Institute.

[33] 55 FR 37601-2, Docket No. NHTSA-1989-09, September 12, 1990.

[34] *See* 85 FR 39678 and 85 FR 39679, Docket No. NHTSA–2019–0079; Notice 2, July 1, 2020.

2. Increase Glare Limit Exceedance Time to Greater Than One-Tenth of a Second

As noted in Section II, Auto Innovators understands the importance of balancing the safety benefits of ADB technology with avoiding discomfort glare to other vehicle motorists. However, the Agency should not diminish the visibility improvements an ADB system can provide to disproportionately protect against discomfort glare. Unfortunately, we believe that the glare limits specified by NHTSA in its test procedure do exactly that. NHTSA is proposing stricter requirements for an advanced system that increases safety with increased visibility; stricter even more than that imposed on AHB systems as discussed above. However, even compliant IIHS top rated lower beam systems today cannot meet the proposed glare requirements.

Our testing demonstrated a need for an illuminance exceedance factor that would allow for some flexibility in system response, yet still account for only a minor portion of time in each test run. For a robust system response that adapts the beams accordingly, it must be allowed time to process and validate the driving environment. To not allow for this can result in false validations or sporadic and frantic adaptations. Such a factor would allow for reliable and repeatable test results despite minor variations in the environment, stimulus vehicles, and system detection and response. An analysis of our test data shows that a majority of exceedances were less than 2.0 seconds. Only a few exceedances were over 2.5 seconds, and these were limited to difficult to detect scenarios, such as testing the stationary motorcycle.

We believe that the Agency intended the 0.1 second momentary spike allowance as only a filter for sensor or environmental noise. Based on our results, we believe that 2.5 seconds is reasonable for an ADB system response. We propose that NHTSA increases the illuminance exceedance time for momentary spikes and the sum of momentary spikes over all test distances (30-220 meters) to a maximum of 2.5 seconds. This glare exceedance limit is allowed in SAE J3069™ and is based on human response time to the sudden appearance of an opposing or preceding vehicle.[35] Advanced ADB headlighting systems will outperform human response. Accordingly, we recommend that NHTSA adopts a glare exceedance limit of 2.5 seconds to align with Canada Motor Vehicle Safety Standard ("CMVSS") 108 and SAE J3069™.

3. Eliminate the Glare Limit Exceedance for Distance

S14.9.3.12.8.1 of the NPRM ignores spikes in the illuminance measurement results over the prescribed limits of 0.1 seconds or 1 meter. Because the testing is conducted at constant speeds, having both a time and distance specification becomes duplicative and does not add any value to the test protocol. For example, in the oncoming scenario with both the VUT and the stimulus vehicle traveling at 70 miles per hour, the vehicles will pass a distance of 1 meter in 0.016 seconds. Because timing holds more

[35] SAE J3069™ (JUN 2016).

relevance in real world driving (for example, comparing response times of an ADB system to the perception response time of a human driver in dipping to lower beams), Auto Innovators believes that the distance exceedance limit should be eliminated and the Agency should instead focus only on time limited exceedances.

C. Allow Horizontal Aim

As set forth in SAE J3069™ and CMVSS 108, and expressed in the December 2018 submission under the previous organization Alliance of Automobile Manufacturers, ADB systems require horizontal adjustment to properly align the beam pattern to the vehicle's camera. This facilitates proper alignment of the beam's area of reduced intensity to prevent discomfort glare to any oncoming or preceding vehicles. This alignment exists at the system level and continues to be necessary in the field where occasional need for lamp replacement can occur, for example, as a result of collision damage.

Horizontal (and vertical) adjustment serve to minimize the area of reduced intensity by allowing more precise calibration of what is directed towards the stimulus vehicle(s). If provisions for accessibility and adjustment of horizontal aim were not incorporated into the final rule, automakers would be required to compensate for any resulting horizontal vehicle variation into the size of the area of reduced intensity, resulting in greatly increasing this area. An area of reduced intensity larger than necessary would significantly reduce the additional light otherwise provided to a driver by an optimal ADB system if horizontal aim and adjustment were permitted.

FMVSS 108 allows horizontal aim only when a vehicle is equipped with on-vehicle headlamp aiming devices ("VHAD"). With the introduction of visual/optical aim, not to mention that they were fraught with shortcomings, VHADs have become obsolete. FMVSS 108 should allow the horizontal aim adjustment of ADB headlamps similar to UNECE and Canada Motor Vehicle Safety Standard regulations to properly align the beam pattern with the vehicle's camera to obtain the minimum size of the area of reduced intensity necessary, and properly position it to prevent discomfort glare to oncoming or preceding vehicles.

The method to horizontally aim each ADB headlamp can take many forms, depending on the specific execution of the ADB system. Each involves an ADB-specific aim calibration mode which is activated either by a dealer or consumer when the vehicle is parked. This mode would illuminate a horizontal aim feature utilizing one or more of the ADB-illuminated elements which have a sufficient vertical gradient that can be used for horizontal aim, just as one does today with vertical aim. The dealer or consumer would use this vertical gradient to properly calibrate the horizontal aim following instructions specified in the service manual or owner's manual.

We request that, for the reasons cited above, provisions be made in FMVSS 108 to allow horizontal aim and adjustment for headlamps performing ADB function, wherever it currently is prohibited. Additionally, for compliance testing, we request that NHTSA ensures headlight aiming for stimulus vehicles be adjusted per the vehicle manufacturer's specifications prior to testing, and that the Agency

considers prescribing performance criteria to ensure that light being emitted by stimulus vehicles does not degrade (e.g., decreased illuminance) over time due to aging.

IV. Conclusion

Auto Innovators requests that NHTSA consider both the feasibility and technical concerns and recommendations outlined above regarding the FMVSS 108 test protocol when drafting the final rule. We do not believe the proposed test protocol is practicable or repeatable, rather it is unnecessarily burdensome for manufacturers. We request that NHTSA reconsiders the proposed test parameters which, as currently written, are overly complicated. Specifically, the Agency should scale back its quantity of dynamic test scenarios and the five-year model year requirement for stimulus vehicle selection.

We also recommend that NHTSA increase the glare limit exceedance time to higher than one-tenth of a second. Specifically, we suggest up to 2.5 seconds as recommended by SAE J3069™ and allowed per CMVSS 108. Our data analysis shows that this time limit is more appropriate for the ADB system to adapt to mitigate glare, while at the same time avoid intermittent and haphazard responses. Additionally, NHTSA should incorporate modified glare limits based on IIHS glare limits into the ADB test procedure, and eliminate the glare limit exceedance for distance. Further, we propose that the Agency reconsider the use of a static stimulus and standardized stimulus lighting, require passage of a percentage of individual illuminance readings to achieve compliance, and allow for horizontal aim. For NHTSA's convenience, we have summarized these recommendations in Table 2 in Appendix D.

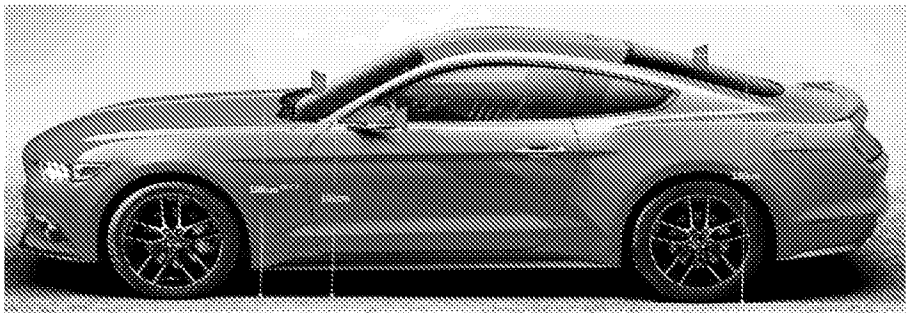
Auto Innovators appreciates this opportunity to provide supplemental comments and hopes that NHTSA grants them their full consideration. We look forward to continuing working closely with the Agency to prioritize safety and innovation and introduce ADB systems in the U.S. vehicle fleet.

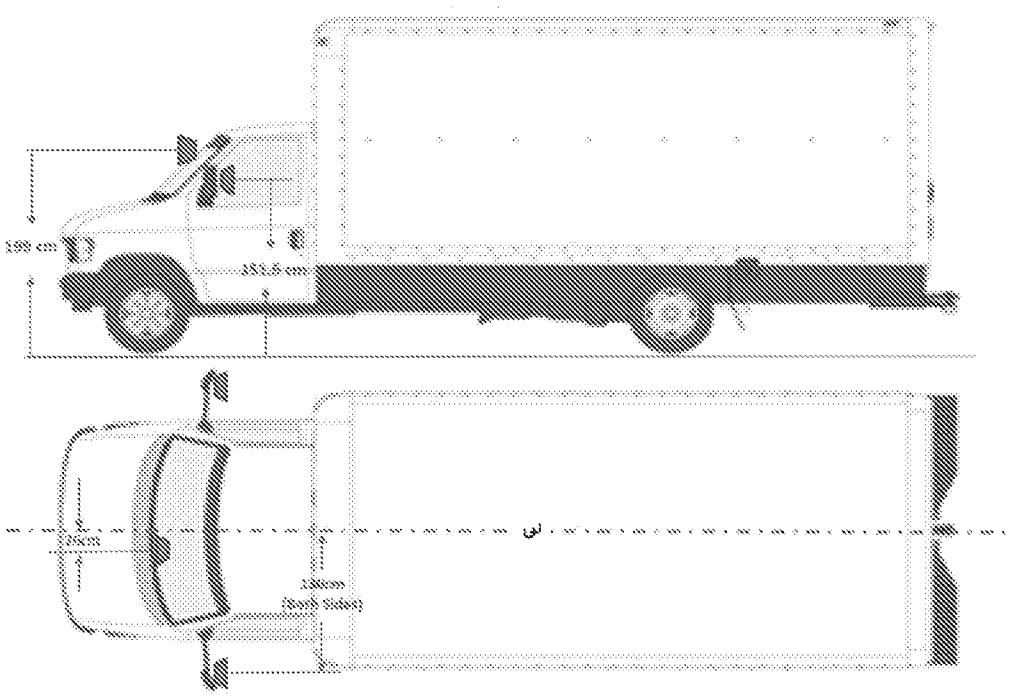
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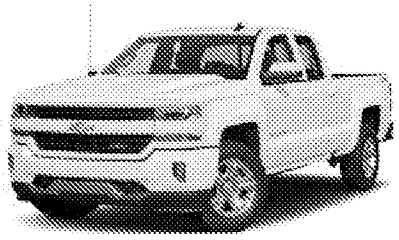
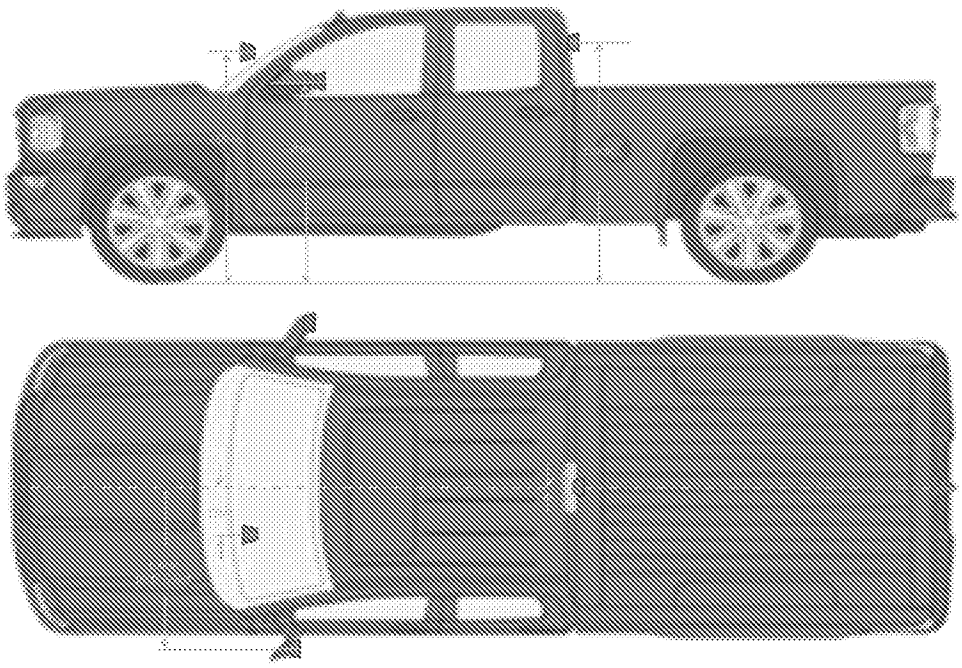


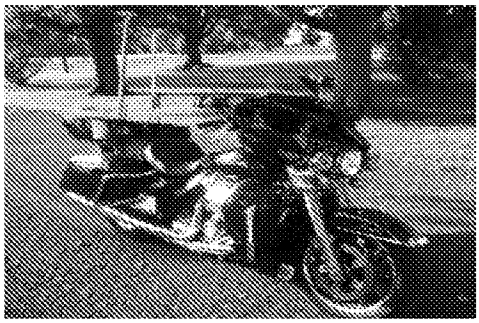
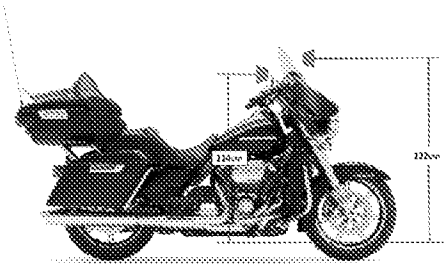
Scott Schmidt
Senior Director, Safety

APPENDIX A – STIMULUS VEHICLES

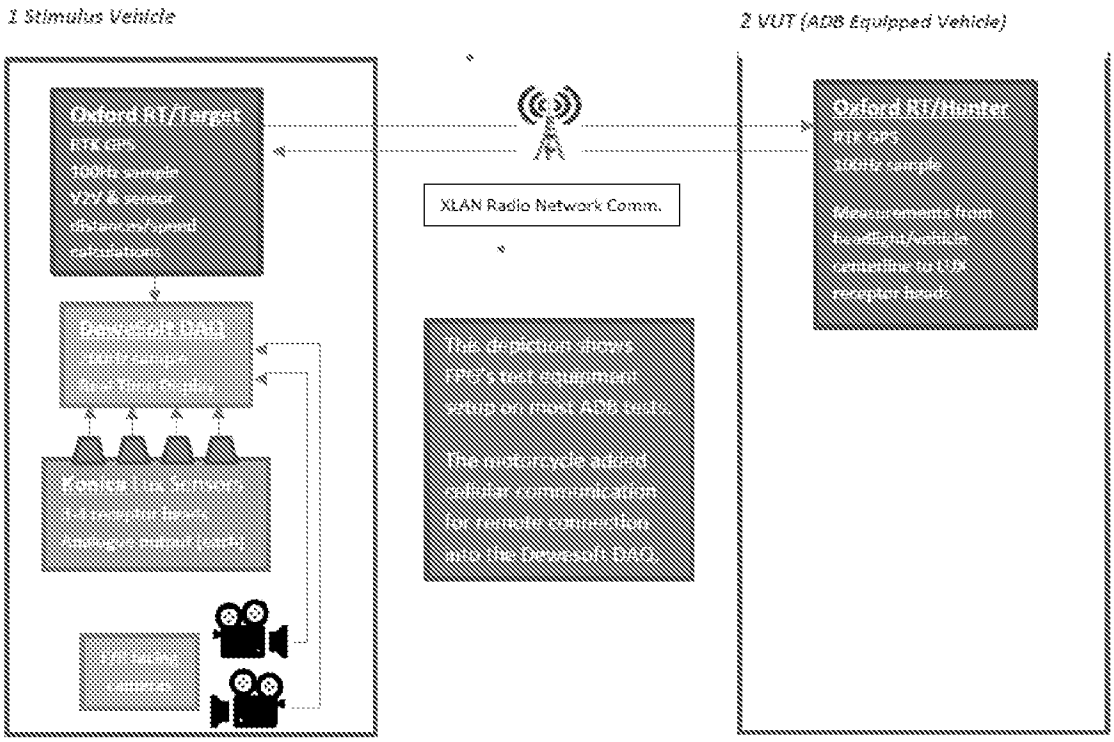
Stimulus Vehicle (Passenger Car)	2018 Ford Mustang GT 
Lamp Type	LED Projector headlamps (low lamp height)
Sensor Placement	 

Stimulus Vehicle (Heavy Truck)	2017 Ford Econoline E-450 (15' U-Haul) 
Lamp Type	Halogen Reflector headlamps
Sensor Placement	Forward Lux sensor placement fit within the NPRM's placement boundary but was very close to the lower limit while placed near maximum windshield height. Wide box, extended towing style mirrors, utilized 3 lux sensors. 

Stimulus Vehicle (Light Truck)	2017 GMC Sierra 1500, 4WD Double Cab/ 2016 Chevrolet Silverado 1500, 4WD Double Cab  
Lamp Type	HID Projector headlamps, utilized 4 lux sensors. While three vehicles were tested against the GMC Sierra 1500, one vehicle was tested against a 2016 Chevrolet Silverado 1500 w/ HID Lamps.
Sensor Placement	

Stimulus Vehicle (Motorcycle)	2018 Harley Davidson Ultra Classic 
Lamp Type	Single LED Projector, forward auxiliary lighting was disabled using only the center source. There was discussion whether to disable the redundant tour pack taillights to create a worst-case scenario for testing. Ultimately, it was decided to keep the taillight array intact, avoiding FMVSS 108 compliance concerns. Also 3 lux sensors were utilized without a sensor placed in the center rearview.
Sensor Placement	Generally, motorcycle windscreens do not extend beyond an operator's line of sight. The NPRM boundaries represent appropriate placement, however, sensor placement on a windscreen within these limits was challenging. The Harley-Davidson motorcycle required placement close to the lower boundary at 1.32 meters, while the rider's sightline position was mid-boundary. Physically lower models of motorcycles may require an elaborate mounting fixture isolated from the windscreen to meet the boundary requirements specified in the NPRM. Further, windscreen mounting can introduce variation when considering frame fixed versus steering fixed (such as our machine).  

APPENDIX B – EQUIPMENT SETUP



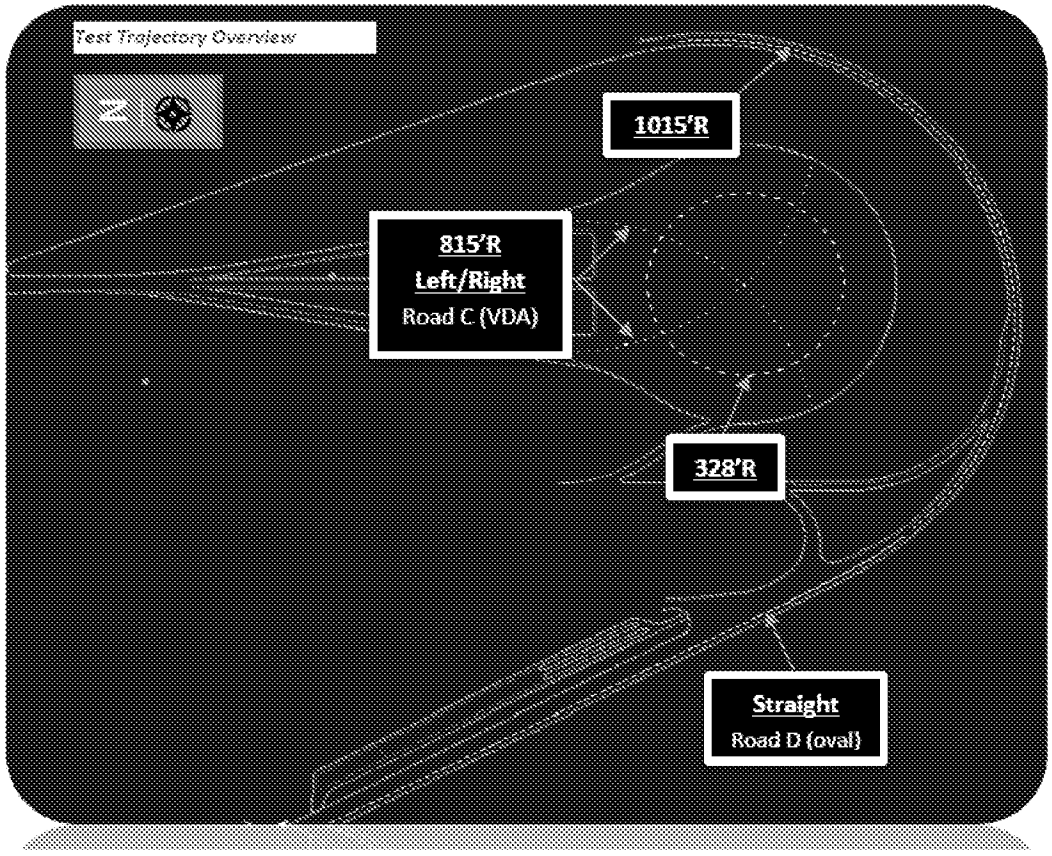
- Oxford Technical Solutions RT3002 (high accuracy GPS), OxTS Range system (Target/Hunter)
- Dewesoft Data Acquisition – customizable hardware, video and data acquisition
- Konica Minolta T-10A LUX receptors – individual analog output recorded by Dewesoft at low gain
- Basic HD USB webcams – forward and rear facing, helpful for visualizing/sorting tests

APPENDIX C – TRACK SETUP

- 1100-1300 ft. Radius Curve (Large) – FTTA selected its oval track (Road D) south curve for this scenario. The actual center line measurement is a 1015 ft radius. Superelevation was at 7%, compared to the 2% specified in the NPRM, and adjacent test lanes were on the same slope. This curve was defined by standard Michigan Department of Transportation (DOT) lane markings (dashed center, solid edge lines, grassy shoulder, partial guard rail).

- 730-790 ft. Radius Curve (Mid) – This test scenario was conducted on FTTA's VDA pad (Road C). Actual centerline radius was 815 ft. between adjacent test lanes. Curvature was defined by short road cones along survey dots, with no edge lines.

- 320-380 ft. Radius Curve (Small) – Also conducted on the VDA pad, with a 328 ft. centerline radius – the only curve in spec of the NPRM. This curvature was defined by DOT specification dashed yellow, but no edge lines. The oncoming 220m "start of test" is not always achievable here, with vehicles only reaching 200m distance (measure by line of sight). Though somewhat irrelevant when vehicles are 180° apart – no oncoming light will be in frame.



APPENDIX D – SUMMARY OF RECOMMENDATIONS

TABLE 2. AFAI SUPPLEMENTAL COMMENTS ADB NPRM REVISION REQUESTS			
NPRM PROCEDURE SUBJECT	REQUESTED PROCEDURE REVISION	REVISION BASIS	NPRM & FMVSS No. 108 SECTION(S) AFFECTED
Transition zone between upper beam and lower beam.	Allow transition zone without photometric requirements	Physical and technical impossibility of providing large changes in light levels across small horizontal distances	S9.4.1.6.6 & S9.4.1.6.7
Glare limits	Allow right curve glare limits used in IIHS headlamp evaluation procedure	More typically represents performance of current OEM headlamps and an appropriate balance of visibility and glare	S9.4.1.6.3 & Table XIX-d
Glare exceedance time interval or distance interval	Allow up to 2.5 seconds and remove distance interval	Represents glare tolerance based upon cumulative dosage exposure	S14.9.3.12.8.1
Photometric performance basis of compliance	Allow compliance to be based upon passage of a percentage of total test scenarios	Recognition of variances implicit in novel outdoor dynamic photometry testing and application of design to conform precedent	S14.9.3.12.8 Reference: S14.9.3.3.3, S14.9.3.4.3, S14.9.3.5.3, S14.9.3.6.3, S14.9.3.7.3, S14.9.3.8.3, S14.9.3.9.3 & S14.9.3.10.3
Static stimulus	Allow a static stimulus such as a test fixture or a stimulus vehicle, and standardized stimulus lighting	Observed safety concerns and stimulus identification issues	ADB Test Matrix Reference: S6.4.3, Table V-b, & Table V-c
Horizontal headlamp aim	Allow horizontal headlamp aim adjustment without use of a VHAD	Permit camera and headlamp alignment on each individual vehicle	S10.18.4
Short (15-29.9 m) distance range	Eliminate 15-29.9 m distance range	Observed small amount of test failures	S9.4.1.6.3 & Table XIX-d
Preceding (Same) lane test scenarios	Eliminate preceding (Same) lane test scenarios	Testing showed infrequent failures	S14.9.3.12.5
Mid and large curve radius test scenarios	Eliminate mid and large curve radius test scenarios	Stringency of straight and small radius curve scenarios negates redundancy of results	S14.9.3.12.5

		with mid and large radius curve scenarios	
Test vehicle maximum speed	Reduce from 70 mph to 55 mph	Observed safety concerns and lack of large truck acceleration performance	ADB Test Matrix
Stimulus vehicle category overlap	Eliminate use of light truck stimulus vehicle	Redundancy of results with passenger car	S14.9.3.12.1
Stimulus vehicle selection	Agency selects a single stimulus vehicle from each prior model year of vehicles, based on the best-selling make and model within each vehicle classification.	Imposes practical limits to size of test vehicle fleets	S14.9.3.12.1

Exhibit 8
AAA Report
April 2019



APRIL 2019

COMPARISON OF EUROPEAN AND U.S. SPECIFICATION AUTOMOTIVE HEADLAMP PERFORMANCE

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Abstract

Vehicle headlamps are a primary safety system. Research data from the National Highway Traffic Safety Administration (NHTSA) reports approximately 25 percent of automotive travel occurs at night. However, nearly 52 percent of all driver fatalities and 71 percent of all pedestrian deaths occur during dark driving times (NHTSA, 2018). This data leads to the conclusion that driving in dark or low-light conditions increases the likelihood of a collision at least partially due to a combination of limited forward illumination by current automotive lighting systems and the speeds at which drivers travel (NHTSA, 2018). The efficacy of headlamps compliant with U.S. regulations may be a contributing factor. Research conducted by AAA determined that modern headlamps on low beam provide adequate lighting for speeds of only 39 mph to 52 mph, depending on the type of headlamp (AAA, 2015).

While urban roadways with overhead lighting can mitigate this problem, a minority of U.S. roadways have installed overhead lighting (Technology, 2014). Additionally, U.S. drivers are reluctant to use high beam headlamps out of concern for creating glare for oncoming or preceding drivers (Mary Lynn Buonarosa, 2008), (AAA, 2015).

Increasing roadway lighting without creating glare for other motorists should increase the safety of nighttime driving. This is the promise of adaptive driving beam headlamp technologies. NHTSA describes adaptive driving beam as, "a type of adaptive front-lighting system that automatically enables upper beam headlamps and adapts their beam patterns to create a shaded area around oncoming and preceding vehicles to improve long-range visibility for the driver without causing discomfort, distraction, or glare to other road users."

The performance specifications for U.S. headlamps are defined by Federal Motor Vehicle Safety Standard 108 that sets requirements for original and replacement lamps, reflective devices, and associated equipment. Many of the specifications were developed for sealed beam headlamps and, even with updates to the regulations, have not kept pace with recent advances in lighting technology. Section 9.4 of the standard expressly prohibits simultaneous operation of high and low beam headlamps, thereby excluding adaptive driving beam headlamp systems from vehicles sold in the U.S.

This research project intends to evaluate the effectiveness and limitations of European specification vehicles equipped with adaptive driving beam technology. U.S. specification headlamp systems and adaptive driving beam technology available on European specification vehicles will be quantitatively and qualitatively compared.

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The vehicles selected for testing were sourced from two vehicle manufacturers who provided both U.S. and European specification vehicles of the same model. The U.S. specification vehicles are equipped with LED headlamps and auto-dimming technology, which allows driving with high beams by default above a set speed, and automatic switching to low beam operation when oncoming or preceding traffic is detected. The European specification vehicles are equipped with LED headlamps and adaptive driving beam technology.

Research Questions:

1. How do U.S. and European specification low and high beam headlamps differ in static roadway illumination?
2. How do U.S. and European specification headlamps differ in producing glare?
3. How do U.S. and European specification headlamps differ in dynamic roadway illumination?

Key Findings:

1. During static testing of roadway lighting, driver perception of target illumination was similar among all vehicles tested.
    a. U.S. specification headlamps produced 1.9% more low beam illumination on targets.
    b. Average target illumination values for high beam was 12.5% higher for European specification as compared to U.S. specification headlamps.
2. All four test vehicles scored in the low perceived glare range of the evaluation scale, ranging from "Satisfactory" to "Just Acceptable". One manufacturer's European specification vehicle scored better than its U.S. specification counterpart did. Results for the other manufacturer's vehicles were reversed.
3. European specification systems consistently provided more roadway lighting when an oncoming vehicle was approaching, or a preceding vehicle was close.
    a. Based on static target illumination data, the increase in roadway lighting could be as much as 86 percent (comparison of average European specification high beam to U.S. specification low beam).
    b. The adaptive driving beam (ADB) system maintained high beam operation in all areas except those intentionally shaded by the system to minimize glare.

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c. In similar vehicle placement circumstances, the U.S. specification vehicles were forced to reduce headlamp operation to low beam in order to minimize the likelihood of producing glare to oncoming and preceding vehicles.

Roadways with hills were the most common driving scenario where other drivers were subjected to potential glare by an ADB capable vehicle. It should be noted that all headlamp systems currently available (manual high-low switching and automatic high-beam) produce glare to other drivers when cresting hills. In this situation, where glare potential is high, AAA research noted that it occurred less frequently with ADB capable European specification headlamp systems than with auto-dimming U.S. specification systems.

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1 Overview

Vehicle headlamps are a primary safety system. Research data from the National Highway Traffic Safety Administration (NHTSA) indicates that roughly 25 percent of automotive travel occurs at night. However, nearly 52 percent of all driver fatalities and 71 percent of all pedestrian deaths occur during dark driving times (NHTSA, 2018). This data leads to the conclusion that driving in dark or low-light conditions increases the likelihood of a collision at least partially due to limited forward illumination by current automotive lighting systems combined with the speeds at which drivers travel.

Previous AAA research concluded that low beam headlamp systems using halogen bulbs and reflector-type optics do not adequately illuminate the roadway at speeds in excess of 39 mph. Projector lens and LED light sources can extend the range of useful roadway illumination and provide sufficient illumination at speeds up to 45 mph, and LED headlamps up to 52 mph. (AAA, 2015).

High beam headlamps improve forward illumination up to 28 percent compared to low beams. Unfortunately, two-thirds (64 percent) of U.S. motorists who drive at night say they do not regularly use their high beam headlamps (AAA, 2015). To address this situation, many automakers are introducing headlamps that can be set to automatically switch between low and high beams based on driving conditions.

An optimal headlamp solution would provide sufficient forward illumination so that a driver, at any reasonable vehicle speed, would always have sufficient time to visually identify and appropriately react to any dangerous roadway condition, including pedestrians, animals and other obstacles. However, safe nighttime driving at posted speed limits on unlit roadways requires more forward illumination than is provided by headlamp systems currently available in the U.S.

Automakers and lighting system designers have worked to close the gap between the speeds at which motorists drive and the required amount of roadway illumination. However, a major challenge in the development of more advanced lighting systems has been limiting glare. Most options for increased roadway illumination can also create glare for oncoming and preceding motorists. Solutions have been developed and are available on selected vehicles sold in Europe and elsewhere in the world. Commonly called adaptive driving beam (ADB) headlamps, these systems allow driving with the high beams always on. Glare is prevented by dynamically controlling segments of the headlamp beam to create "shadowed" areas in the locations of oncoming and preceding vehicles. These dynamic, adaptive

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driving beam systems have the potential to deliver increased roadway illumination for safer driving at higher speeds while shielding other drivers from glare.

2 Regulatory limitations to allowing advanced headlamp systems in the U.S.

Federal Motor Vehicle Safety Standards (FMVSS) developed by NHTSA specify technical requirements for all vehicles sold in the United States. Automotive headlamps are regulated by FMVSS 108. This regulation clearly defines headlamp performance, installed position, luminescence, considerations for glare, and aiming for both low beams and high beams. Although FMVSS 108 does not specifically address or prohibit the use of ADB lighting systems, certain technical requirements have been interpreted to rule out their use. Two relevant sections of FMVSS 108:

- §9.4: Low and high beam headlight beams cannot be energized at the same time. This is a fundamental obstacle to allowing ADB headlamp systems in the U.S.
- §6.1.5.2.1 to §6.1.5.2.3: These sections detail scenarios where high and low beams are allowed to be used simultaneously, but they do not include the basic function of ADB systems.

FMVSS 108 also outlines detailed photometric requirements for both low and high beams. ADB headlamps use a combination of low and high beams at the same time, and deactivate the lights in specific areas to prevent glare. Unfortunately, this dynamic lighting control makes ADB headlamps unable to meet all of the requirements specified in the FMVSS standard.

2.1 Canadian Regulatory Requirements

Canadian regulations for vehicle headlamps (CMVSS - Canada Motor Vehicle Safety Standard) are very similar to those in the U.S. However, CMVSS 108, the Canadian counterpart to FMVSS 108, was amended in March 2018 to permit the use of European-style headlamps equipped with ADB capability (Canada, 2018). The regulation states that headlamps may be used, provided they comply with either the requirements detailed in the relevant United Nations Economic Commission for Europe (UNECE)[1] headlamp regulations as described below or the ADB test procedure described by the Society of Automotive Engineers (SAE) Recommended Practice J3069 201606..

[1] The World Forum for Harmonization of Vehicle Regulations is a working party of the Sustainable Transport Division of the United Nations Economic Commission for European (UNECE). It is tasked with creating a uniform system of regulations, called UN Regulations, for vehicle design to facilitate international trade.

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2.2 United Nations Regulatory Requirements

UNECE regulations 48 and 123 (UNECE, 2018) include the most significant sections pertaining to the function and use of ADB headlamps in the European Union (EU). As part of the Transatlantic Trade and Investment Partnership, a study was completed comparing the differences between U.S. regulations and those enforced in EU countries. The differences are summarized below:

EU (UN Regulations)		U.S. (FMVSS/SAE Standards)	
Signal (Applicability)	Functional Intent	Signal (Applicability)	Functional Intent
Adaptive Front-Lighting System (AFS) [Optional]	A lighting device that provides beams with differing characteristics for automatic adaption to varying conditions of use for the dipped-beam (passing-beam) and the main-beam (driving-beam) (R48, 2.7.28)	Full Adaptive Forward Lighting System (AFS) [Optional]	No formal definition in SAE standard (J2838)

Figure 1: Regulatory Requirement Differences Regarding ADB Systems, EU vs US (Broertjes, 2018)

The UN regulation directly defines the functional intent of adaptive driving beam headlamps and permits their use as part of its regulatory construct, while U.S. regulations do not. For a detailed description of the differences between U.S. and EU lighting requirements, refer to the full study cited in the bibliography.

3 Technology Description

U.S. and European regulations are similar in defining both low beam and high beam headlamps. The high beam is primarily for distance, and to illuminate the roadway when not closely following or meeting oncoming vehicles. The low beam is intended to illuminate the roadway and immediate area ahead of the vehicle when closely following or meeting an oncoming vehicle (Broertjes, 2018).

Some countries have changed from U.S. to UNECE regulations in the past: the UK in the 1970s, Australia in the 1980s, and Japan in the 1990s.

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3.1 Allowances and Limitations of U.S. Regulations

The following points summarize U.S. regulatory requirements related to the twin goals of providing adequate roadway lighting and minimizing glare to oncoming and preceding drivers.

- According to U.S. regulations, low beam and high beam headlamps are required to operate independently. This requirement is interpreted to specifically excludes ADB lighting systems due to their always-on high beam with low beam projection where appropriate (shuttering oncoming or preceding vehicles).
- Illumination of targets to the side of the roadway has been found to be much higher with U.S. specification low beam headlamps (Federal Register, 2018).
- U.S. regulations allow higher mounting heights for headlamps (up to 52 inches, which is 6.77 inches (172mm) above the European limit). This can contribute to glare as the height of the headlamp approaches the level of the driver and mirrors in other vehicles. Compounding this problem, U.S. regulations do not require vertical aiming adjustment based on mounting height. (The higher the headlamp is mounted on the vehicle, the more it is angled downward.) This can result in large vehicles, such as pickup trucks and SUVs directing more light at greater elevations above the road. Current U.S. regulations only require headlamps to be compliant when tested in the lab. The practice of allowing headlamp mounting above the typical height is inconsistent with the goal of reducing glare to drivers of an oncoming or preceding vehicle (Federal Highway Administration, 2014).
- The measured limits of light output in headlamp beam areas that produce glare are over twice as large in U.S. regulation as compared to UNECE regulation limits (Official Journal of the European Union, 2018).
- Current U.S. regulations do not quantify glare.
- U.S. regulations treat cleaning (washing systems) of headlamps as optional.

3.2 Comparison to Automotive Lighting Standards in Europe

European lighting regulations are documented in United Nations Economic Commission for Europe UNECE regulations, which have been adopted by most countries in the world with the exception of the United Stated and Canada. Two differences in current UNECE regulations and those of the U.S. have to do with allowable high beam intensity and headlamp mounting height. Higher allowable limit for high beam intensity means more light on the roadway and better safety when using high beam headlights. The lower limit for headlamp mounting height in the UNECE regulations means that the source of automotive headlight beams is most likely below the height of eyes of drivers in oncoming or preceding vehicles, thereby reducing the chance for glare.

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- European lighting standards (UNECE) allow over two times the light output from high beam headlight systems as compared to the U.S. (Broertjes, 2018). U.S. compliant systems allow a vehicle maximum of 150,000 candela while European compliant systems allow a vehicle maximum of 430,000 candela (Official Journal of the European Union, 2018). This provides for gains in sight distance, but also increases the potential for glare to affect oncoming and preceding traffic when high beams are not dimmed.
- The allowable mounting height limit of headlamps in UNECE regulated markets is 6.77 inches (177mm) lower than in the U.S. and UNECE regulations require increasing the downward inclination of the headlight beam as the mounting height is increased
    - Vehicles manufactured for a world market have a headlamp mounting height compliant with UNECE requirements, even in the U.S. version.

3.3 ADB Use Case Scenarios

The following visual representations of five use cases depict the on-road scenarios considered when evaluating the performance of ADB in terms of visibility for the driver and glare for other drivers. Use cases support the development of test cases that can be used throughout the automotive industry and with regulators.

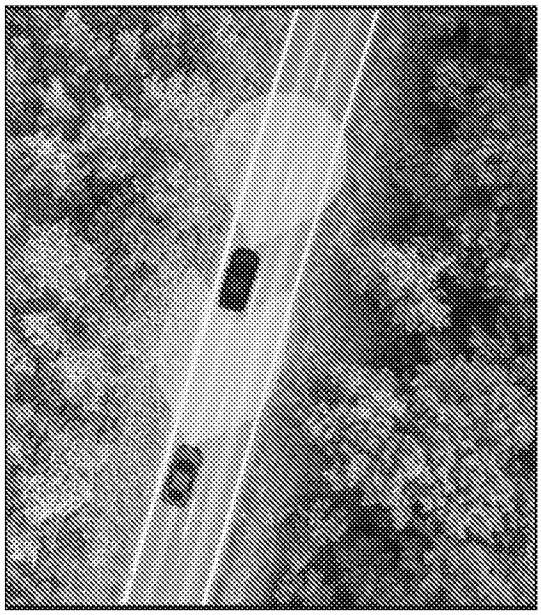


Figure 2: Use Case Scenario 1 Preceding, Straight, Two Car (RH drive depicted)

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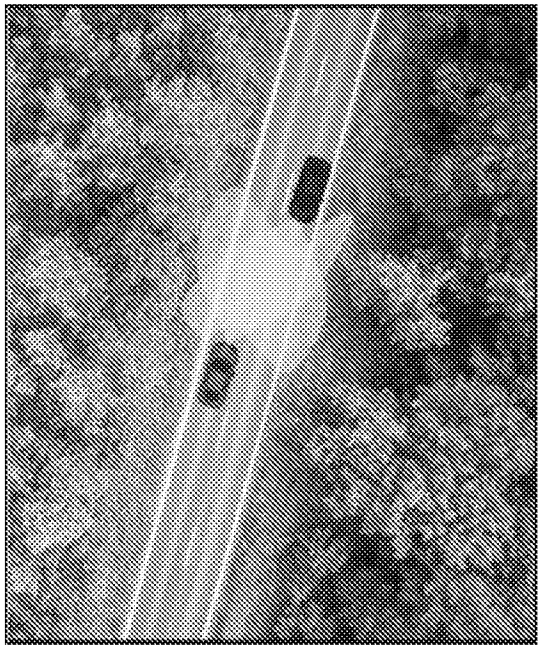


Figure 3: Use Case Scenario 2 Oncoming, Straight, Two Car (RH drive depicted)

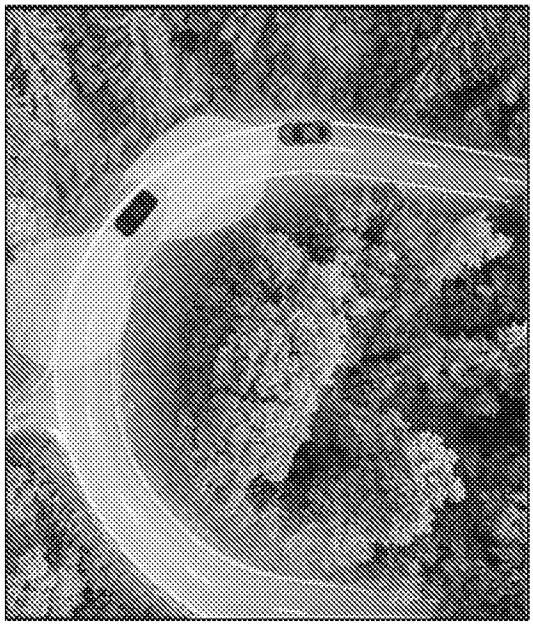


Figure 4: Use Case Scenario 3 Preceding, Curved, Two Car

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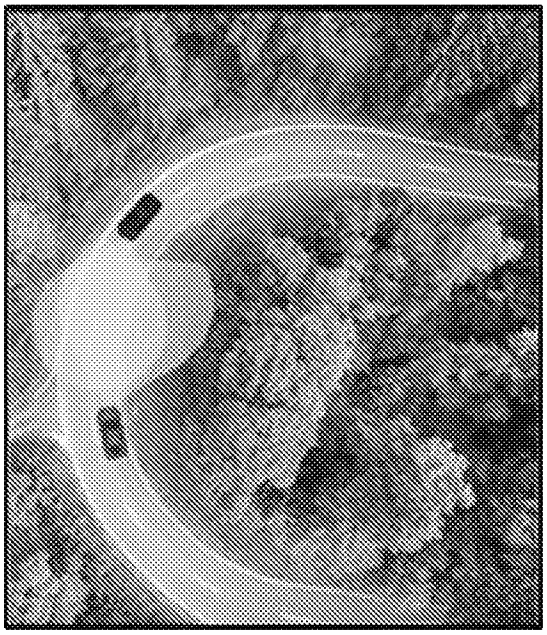


Figure 5: Use Case Scenario 4 Oncoming, Curved, Two Car

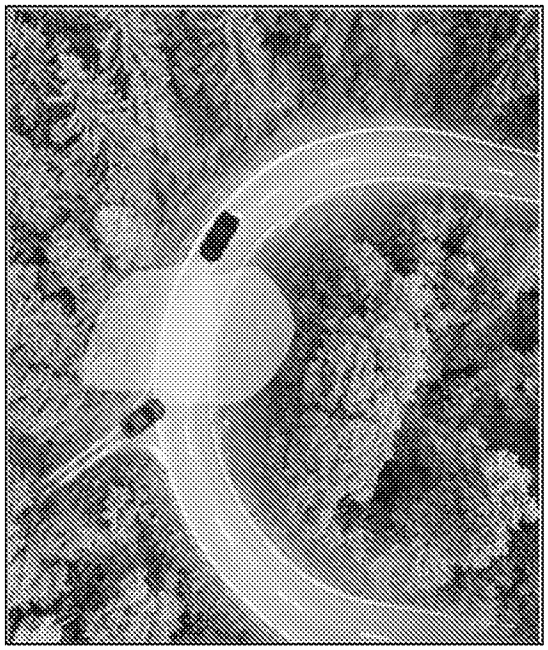


Figure 6: Use Case Scenario 5 Oncoming, Curved Intersection, Two Car

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3.1 ADB Certification and Testing for Regulatory Approval

Headlamp testing for regulatory compliance in the U.S. currently involves evaluating a headlamp as a separate piece of equipment in a lab. Fixed high and low beam patterns are measured with a static photometric test. While this static testing environment can capture photometric properties, it does not capture all aspects of on-road illuminance and performance, particularly for a dynamic system like adaptive driving beam. ADB adapts the light pattern based on the presence and location of other vehicles. The performance of ADB headlamps is dependent on the presence and location of other vehicles, as well as the camera/sensor, software, and mechanism used to control the beam pattern. Evaluation of ADB performance requires whole-vehicle track testing to replicate the presence of other vehicles and measure the glare perceived.

The Society of Automotive Engineers (SAE International) developed J3069, a recommended practice that includes test procedures, performance requirements, and design guidelines for ADB systems (SAE International, 2016). The road test conditions include a stationary fixture that represents a preceding or oncoming vehicle and houses sensors at locations representing drivers' eyes and rear-view mirrors for measuring glare. SAE International recommends that the illuminance at these locations should not exceed glare levels from low beam headlights that meet the current FMVSS 108 regulations. Glare level limits were derived from angular photometric requirements from the current standard FMVSS 108.

In addition to testing for ADB, NHTSA has considered the whole-vehicle testing approach for existing headlamp technology. The Insurance Institute of Highway Safety (IIHS) headlamp safety testing of currently available systems indicates that although a headlamp may meet the lab testing requirements, the on-road performance may not be as safe as desired due to systemic factors including headlamp aim (IIHS, 2016). If whole-vehicle testing were pursued, performance would be based on illuminance provided by the headlamps on the road as installed on the vehicle rather than the light properties of the headlamps as an individual component. By utilizing whole-vehicle testing, regulation can be based on dynamic road visibility and glare performance as perceived by end users.

3.2 U.S. Headlamps versus ADB

Improvements in visibility could be a factor in decreasing the number of road fatalities that occur at night. Numerous studies have highlighted that drivers infrequently use their upper beam headlamps. A study by the University of Michigan Transportation Research Institute (UMTRI) indicated that drivers turned on high beams only approximately 25 percent of the distance driven in nighttime situations

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where their use would be reasonable and advisable (Mary Lynn Buonarosa, 2008). This percentage was confirmed by a AAA survey in 2015 (AAA, 2015). There are several potential reasons for this lack of use per the IIHS. Some drivers may be concerned about causing glare for other drivers. Others may forget to use their high beams or not realize the benefit of high beams over low beam lighting. The added visibility provided by high beams gives drivers more stopping distance and may minimize damages in the event of an accident or prevent an accident from happening in the first place.

An ideal headlamp system maximizes visibility while limiting glare for others. Low beams offer low glare potential for others at the expense of visibility for the driver. High beams provide more visibility but can cause excessive glare for other drivers in the vicinity. High beam assist is a technology available that automatically switches between low beams and high beams, so drivers can have the visibility of high beams when other vehicles are not in the vicinity. When another vehicle is detected, the system automatically switches to the low beam setting until the other vehicle has passed. This technology is a remedy for the under-utilization of high beam, though ADB provides even further enhancements to visibility and safety. NHTSA states, "Adaptive Driving Beam (ADB) is a type of adaptive front-lighting system that automatically enables upper beam headlamps and adapts their beam patterns to create a shaded area over oncoming and preceding vehicles. This functionality improves long-range visibility for the driver without causing discomfort, distraction, or glare to other road users."

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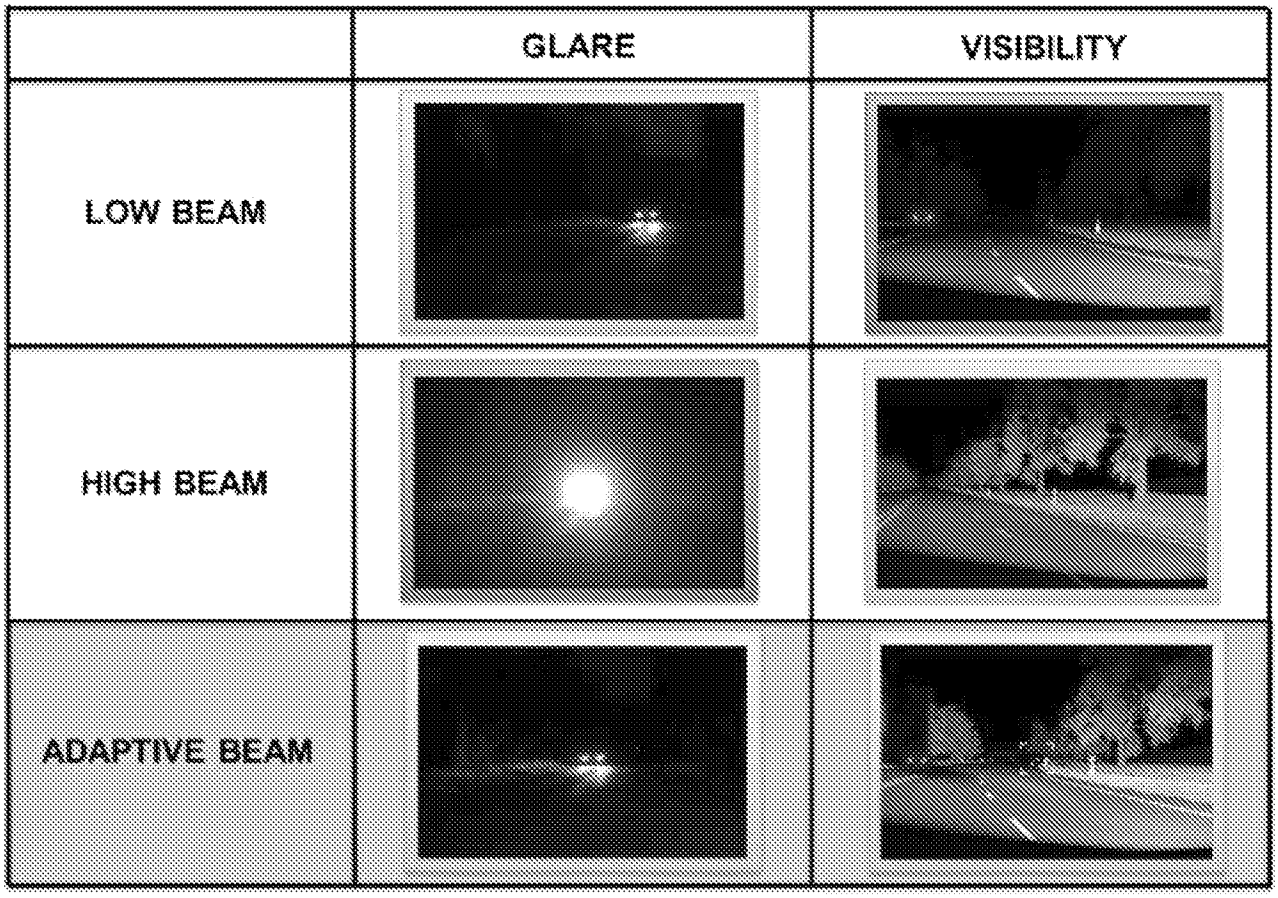


Figure 7: Comparison of glare and visibility provided by low beam, high beam, and adaptive beam. (Bullough, HELLAGroup)

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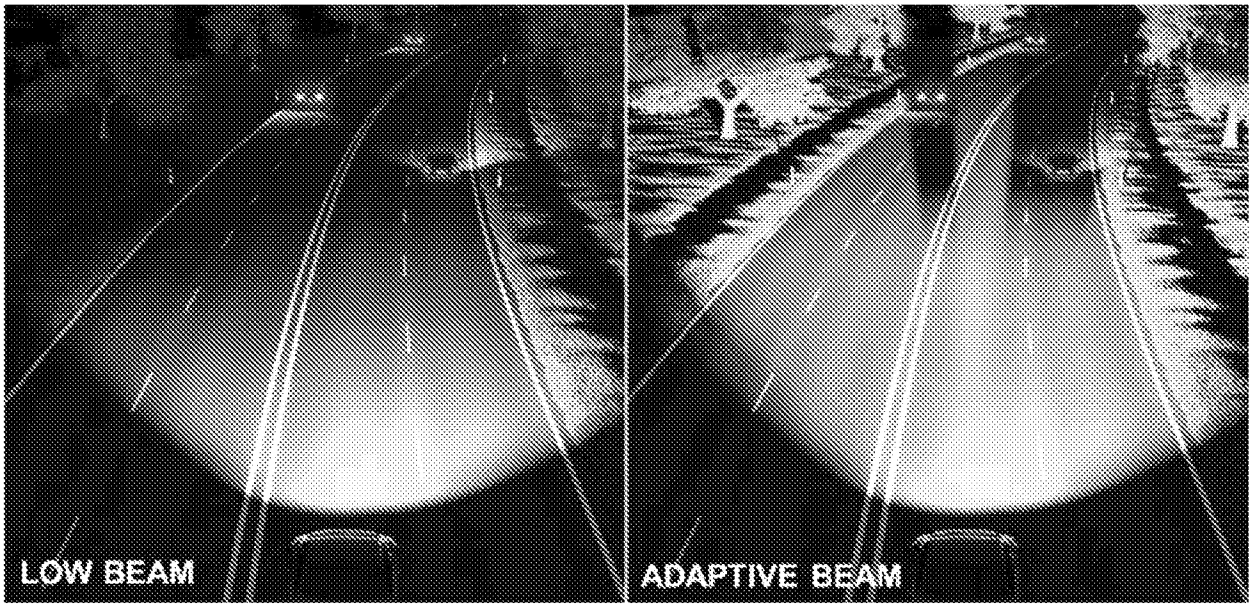


Figure 8: Visual comparison of illumination – low beam versus adaptive beam (HELLAGroup)

3.1 Test Vehicles

Test vehicles were sourced from Volkswagen Group of America (Audi) and Mercedes-Benz USA. The vehicle description was obtained from a uniform set of questions answered by U.S. representatives of each vehicle manufacturer. Vehicle manufacturer representatives were present during static and closed course testing and verified proper operator selections to enable both automatic dimming (U.S. specification) and adaptive driving beam (European specification).

The following four vehicles were made available to AAA researchers for testing.



Figure 9: Test vehicles used in AAA research (image AAA)

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3.1.1 2018 Audi A8

3.1.1.1 U.S. Specification vehicle

The test vehicle sourced from Audi Research and Development is a pre-development model with a headlamp system fully compliant for the U.S. market. Additional information about the test vehicle includes:

- Equipped with LED and auto-dimming headlamps
- Lighting package includes the HD Matrix design LED headlights and OLED taillights
  - Option price for this headlamp package is $3,400
  - Vehicles with this option package are sold in the U.S. and are fully compliant with U.S. regulations. Audi can update to full matrix beam (ADB) functionality with a software update should the regulations change
  - This lighting system is an upgrade. The entry-level system uses a different non-matrix LED system that has fewer modules installed and includes high beam assist.

3.1.1.2 European Specification Vehicle

The test vehicle sourced from Audi Research and Development is a pre-development model with a headlamp system fully compliant for the European market. Additional information about the test vehicle includes:

- Test vehicle is equipped with HD Matrix LED headlamps.
- Detailed information and feature description for the installed lighting package is accessible on the following VW/Audi website: https://bit.ly/2BSqF2T.
- The marketing name for the lighting package is LED mit Laserlicht and can be purchased independently of a package, which is common in Europe.
- An LED Matrix system is standard equipment on the European specification A8.

3.1.2 2018 Mercedes E-Class

3.1.2.1 U.S. Specification Vehicle

The test vehicle sourced from Mercedes Benz Research and Development and is a 2018 E300 4MATIC with headlamp system fully compliant for the U.S. market. Additional information about the test vehicle includes:

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- Vehicle is manufactured in Germany, imported and available for sale in the U.S.
- Equipped with LED headlamps and ADB Assist, which is part of the LED Intelligent Light System headlamps application.
- Information and feature description for the installed lighting package is provided in the vehicle owner's manual (pages 114-118), accessible on the following Mercedes-Benz website: https://bit.ly/2QbiosC. The website URL and page reference are provided by the vehicle manufacturer.
- The LED Intelligent Light System headlamps are only available within the "Premium 2 Package" at an option price of $6,600.
- The marketing name, LED Intelligent Light System, is named MULTIBEAM LED in other markets where it also includes the full package of low and high beam functions.
- These specific headlights are only sold in the United States and Canada. Other markets have the same headlights and same hardware, but as MULTIBEAM LED, have more capabilities and better performance due to the use of different software.
- In the U.S., the tested lighting system is offered as an upgrade for E-Class models but comes as standard equipment for S-Class models (known as Intelligent Light System with Ultra Wide Beam headlamps).

3.1.2.2 European Specification Vehicle

The test vehicle sourced from Mercedes Benz Research and Development is a pre-development model with a headlamp system fully compliant for the European market. Additional information about the vehicle includes:

- The installed headlamps are available in European E-Class models since 2016.
- Equipped with LED Headlamps.
    - The marketing name of the ADB system is MULTIBEAM is consistent in all markets except U.S. and Canada (although Canada now allows MULTIBEAM). Full description of the MULTIBEAM LED is available at: https://bit.ly/2E04PF4, https://bit.ly/2BUEDul and https://bit.ly/1MhNosV.
    - The option price in Germany for the installed headlamp package is 2.320,50 Euro ($2,642 USD[2]).
    - The latest headlight technology includes an additional ULTRA RANGE high beam module. However the test vehicle in this study did not have this included. MULTIBEAM LED with ULTRA

[2] Online currency conversion December 6, 2018

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RANGE high beams were first introduced in the Mercedes S-Class facelift for the 2018 model year. This headlight system is currently offered for C-Class models, CLS-Class models and will be available for other carlines in the future. Additional information is available is provided by the vehicle manufacturer: https://bit.ly/2SBtOD1 and https://bit.ly/2RCiPc2.

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4 Inquiry #1: How do U.S. and European specification low and high beam headlamps differ in static roadway illumination?

4.1 Objective

Quantitatively and qualitatively, evaluate the light output of U.S. and European specification low and high beam headlamps to discern any differences between the two.

4.2 Methodology

The purpose of this evaluation is to quantify the effectiveness of low and high beam headlamp systems in illuminating the roadway ahead of the vehicle. AAA researchers independently conducted all testing on a closed-course.

Dynamic functionality, when the vehicle is driving[3] as opposed to stopped, of U.S. vehicles allows driving with high beam headlights on all the time and automatically switching to low beam when an oncoming or preceding vehicle is noted by the vehicle sensors. This functionality is active during the drive-by glare testing.

Dynamic functionality of the European specification vehicles, equipped with adaptive driving beam (ADB) headlamp systems, is activated during the drive-by glare testing.

Both vehicle manufacturers offer additional long-range headlamp functionality (for open road driving at sustained speeds) which was not evaluated in this test[4].

4.2.1 Quantitative Evaluation

The closed-course area used for this test consisted of an unlighted level asphalt surface approximately 1,300 feet long and 30 feet wide. Testing was initiated at least ninety minutes after sunset to ensure that ambient lighting was typical of an unlighted roadway during nighttime hours. Non-reflective black targets with a square cross-section (12" sides) were deployed throughout the testing lane. Targets were arranged to provide evaluation points directly ahead of the test vehicle as well as toward the left and right-hand sides of the roadway. Figure 11 describes the target placement for testing. All distances

[3] Automatic dimming headlamp systems and ADB work above a minimum speed, which is set by the vehicle manufacturer.
[4] Refer to "Test Vehicles", section 3.8 for additional details and resources to learn more about optional lighting systems available in both the U.S. and European markets.

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are in reference to the front center point of the test vehicle. A positive lateral distance is to the driver's side, or left of the vehicle, and a negative lateral distance is to the right.

For consistency, each test vehicle was placed in an identical orientation facing the targets. For European specification vehicles, the ADB system was switched off, and low beam or high beam mode was selected manually.

During testing, the vehicle's engine was allowed to idle to ensure a stable voltage supply to the headlamps. The instrument panel lighting was adjusted to mid-way between minimum and maximum settings. The low beam downrange light intensity was measured on the vehicle-facing surface of each target with a calibrated light sensor facing directly toward the test vehicle. After the light intensity at each target was measured, the high beams were switched on and the light intensity measurements were repeated at each target.

4.2.2 Qualitative Evaluation

The test setup described in Section 4.2.1 was used for qualitative evaluations. Five (5) AAA researchers participated in "driver" perception testing. A brief description of each researcher is provided below.

#	Sex	Age	Vision
1	M	50s	Glasses
2	M	50s	Glasses
3	M	20s	No Correction
4	M	30s	No Correction
5	M	40s	Reading Glasses

Figure 10: Researcher description

To ensure researchers were acclimated to the dark, a minimum of ninety minutes was spent in nighttime ambient conditions without the presence of light sources prior to test participation. For the evaluation, each researcher reported on his perception of each non-reflective target. Specifically, researchers would rate target perception in terms of one (1) out of three (3) possible outcomes.

1. Object is clear enough that you would take immediate measures as a driver to avoid it.
2. Object is noted, but its outline is unclear or vague enough that you would not take immediate action to avoid it.
3. Object is not discernable with a maximum of two seconds effort.

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The scores from each researcher are summed for all test vehicles to provide a comparison of lighting efficiency while the vehicle is stopped (neither ADB or automatic dimming is active).

Target	Longitudinal Distance (ft)	Lateral Distance (ft)
1	100	24
2	100	34
3	150	9
4	200	7
5	250	5
6	300	-9
7	350	-6
8	400	-3
9	500	0
10	600	6
11	700	0
12	800	-6
13	1000	0

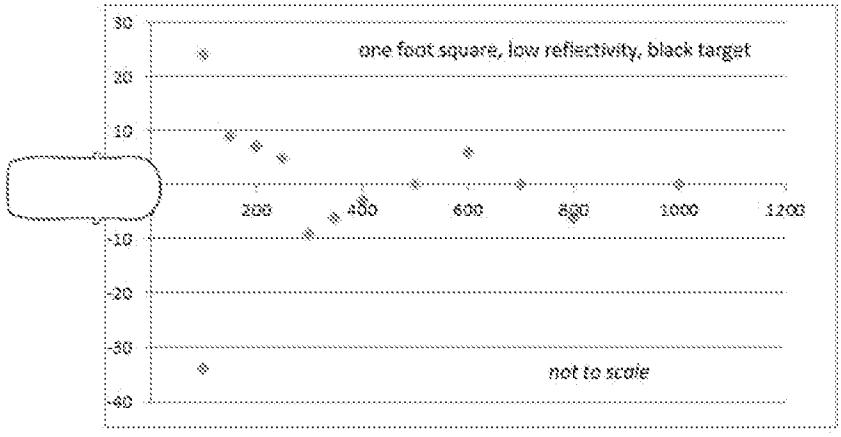


Figure 11: Placement of lights for target illumination evaluation

Each researcher performed the evaluation with low beam headlamps and then repeated the procedure with high beam headlamps. Each test vehicle was evaluated by researchers in the same sequence to minimize variation between vehicles.

The purpose of the evaluation is to determine whether researchers' abilities to discern non-reflective objects is affected by headlamp specification. Due to differences in eyesight, it is expected that this ability will vary somewhat between individuals.

4.3 Key Findings

Driver perception of target illumination during static testing was similar among all vehicles tested.

The U.S. specification vehicles produced 1.9% more low beam illumination on targets. This finding is in line with NHTSA support of U.S. low beam patterns over European specification (Federal Register, 2018).

The average target illumination values for high beam was 12.5% higher for European specification vehicles compared to U.S. specification. This is unsurprising considering the higher output allowed for high beam operation in European specification vehicles (430,000 cd vs. 150,000 cd for U.S. specification).

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All test vehicles (U.S. and European specification) were equipped with premium LED headlamps and performed in the expected range of that headlamp system.

4.4 Vehicle Testing Results

Individual vehicle results are anonymized in this report. Assignment of number 1 or 2 to Audi and Mercedes was accomplished by coin toss. The goal of this research is not to compare specific manufacturers, but to assess the differences between U.S. and European specification headlamps. Anonymized results are credited as follows:

- "U.S. specification, manufacturer 1"
- "European specification, manufacturer 1"
- "U.S. specification, manufacturer 2"
- "European specification, manufacturer 2"

Thirteen black targets, area approximately one-foot square and low reflectivity, were viewed by the panelists in an array as shown in the images in this section.

The sum total scores across all five panelists were tallied for each vehicle. In addition, the illumination from the test vehicle headlamps that fell on the targets was recorded and summed across all targets.

The European specification, manufacturer 1 low beam scored slightly lower than the U.S. specification manufacturer 1 low beam, with a score of 49 to 52 respectively. In high beam operation, the European specification, manufacturer 1 high beam performed better (with a score of 60) compared to the U.S. specification, manufacturer 1 high beam (with a score of 50). The total illumination on the targets for U.S. specification, manufacturer 1 low beam was a total of 103.9 lux on the targets versus 96.7 lux for the European, specification manufacturer 1 ADB. Both manufacturer 1 high beam totals were similar, with 141.48 lux for the U.S. specification headlamp versus 151.21 lux for the European specification manufacturer.

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Figure 12: Target illumination view from U.S. specification mfg. 3, low beam

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	U.S. Spec Manufacturer 1 - Low Beam					Target
			researcher			Illumination
Target	2	4	1	5	3	(Lux)
1	2	2	2		2	15.61
2	0	2	2		1	4.16
3	2	2	2		2	16.78
4	2	2	2		2	14.98
5	2	2	2		2	12.25
6	0	2	2		1	9.53
7	0	2	2		1	8.84
8	0	2	2		1	7.50
9	0	0	0		0	5.08
10	0	0	0		0	3.27
11	0	0	0		0	2.52
12	0	0	0		0	2.22
13	0	0	0		0	1.16
average	1.00				average	7.99
SUM	**52**				**SUM**	**103.90**

Figure 13: Target perception and illumination scores U.S mfg. 1, low beam

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	U.S. Spec Manufacturer 1 - High Beam					Target
			researcher			Illumination
Target	2	4	1	5	3	(Lux)
1	2	2	2		2	12.39
2	0	2	0		0	2.88
3	2	2	2		2	41.15
4	2	2	2		2	26.05
5	2	2	2		2	17.00
6	0	2	2		1	9.90
7	0	2	2		1	8.41
8	0	2	2		0	7.44
9	0	1	1		0	5.40
10	0	0	0		0	4.12
11	0	0	0		0	2.88
12	0	0	0		0	2.42
13	0	0	0		0	1.44
average	0.96				average	10.88
SUM	**50**				**SUM**	**141.48**

Figure 14: Target perception and illumination scores U.S mfg. 1, high beam

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Figure 15: Target illumination view from European specification mfg. 1, low beam

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	Euro Spec Manufacturer 1 - Low Beam					Target
	researcher					Illumination
Target	2	4	1	5	3	(Lux)
1	2	2	2	2	2	27.20
2	0	1	0	0	0	2.13
3	2	2	2	2	2	24.11
4	2	2	2	2	2	14.20
5	2	2	2	2	2	8.80
6	0	2	1	0	1	5.04
7	0	1	1	0	1	4.31
8	0	0	0	0	1	3.63
9	0	0	0	0	0	2.59
10	0	0	0	0	0	1.87
11	0	0	0	0	0	1.23
12	0	0	0	0	0	1.12
13	0	0	0	0	0	0.47
average	0.75				average	7.44
SUM	**49**				**SUM**	**96.70**

Figure 16: Target perception and illumination scores European mfg. 1, low beam

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	Euro Spec Manufacturer 1 - High Beam					Target
	researcher					Illumination
Target	2	4	1	5	3	(Lux)
1	2	2	2	2	2	27.23
2	0	1	0	0	0	2.09
3	2	2	2	2	2	48.73
4	2	2	2	2	2	26.33
5	2	2	2	2	2	15.18
6	0	2	2	2	2	7.12
7	0	2	2	1	2	6.46
8	0	1	2	0	1	5.70
9	0	0	0	0	0	4.22
10	0	0	0	0	0	3.36
11	0	0	0	0	0	2.10
12	0	0	0	0	0	1.79
13	0	0	0	0	0	0.90
average	0.92				average	11.63
SUM	**60**				**SUM**	**151.21**

Figure 17: Target perception and illumination scores European mfg. 1, high beam

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Figure 18: Target illumination view from U.S. specification mfg. 2, low beam

The target recognition for the U.S specification, manufacturer 2 low beam was lower with a score of 40, compared to the European specification, manufacturer 2, which scored 46.

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	U.S. Spec Manufacturer 2 - Low Beam					Target
	researcher					Illumination
Target	2	4	1	5	3	(Lux)
1	2	2	2	2	2	14.88
2	0	0	0	0	0	4.57
3	2	2	2	2	2	13.98
4	2	2	2	2	2	8.63
5	2	2	2	2	2	5.93
6	0	0	0	0	0	3.04
7	0	0	0	0	0	2.70
8	0	0	0	0	0	2.54
9	0	0	0	0	0	1.98
10	0	0	0	0	0	1.54
11	0	0	0	0	0	1.00
12	0	0	0	0	0	0.94
13	0	0	0	0	0	0.44
average	0.62				average	4.78
SUM	**40**				**SUM**	**62.17**

Figure 19: Target perception and illumination scores U.S mfg. 2, low beam

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	U.S. Spec Manufacturer 2 - High Beam					Target
	researcher					Illumination
Target	2	4	1	5	3	(Lux)
1	2	2	2	2	2	19.02
2	0	2	2	2	2	9.38
3	2	2	2	2	2	33.40
4	2	2	2	2	2	21.84
5	2	2	2	2	2	14.88
6	0	2	2	2	1	7.64
7	0	2	2	2	1	6.94
8	0	1	1	0	0	6.43
9	0	0	0	0	0	4.49
10	0	0	0	0	0	3.56
11	0	0	0	0	0	2.45
12	0	0	0	0	0	2.05
13	0	0	0	0	0	1.23
average	0.98				average	10.25
SUM	**64**				**SUM**	**133.31**

Figure 20: Target perception and illumination scores U.S mfg. 2, high beam

The European specification, manufacturer 2 high beam scored marginally better when compared to the U.S. specification, manufacturer 2 high beam with a score of 66 versus 64.

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