

Solid-State Light Sources and Light Measurements in Automotive Lighting

Jianzhong Jiao, Ph.D., SAE Fellow
JZJ Consulting, Inc.
November 16, 2021



International Commission on Illumination
Commission internationale de l'Éclairage
Internationale Beleuchtungskommission



Canadian National Committee - Comité national canadien

Outline



- Basics of Automotive Lighting
- Solid-State Light Sources Used in Automotive Lighting
- Automotive Lighting Measurements
- Performance-Based Measurements

Basics of Automotive Lighting



Functions

- **To see – Road illumination devices, RID**
 - An illumination device provides sufficient light to illuminate the objects or surroundings so that human eye can detect (see) them.
 - “Sufficient” light is dependent on human eye’s visibility, and human eye’s visibility varies.
- **To be seen – Signaling and marking devices, SMD**
 - An illumination device serves as an indicator, marker, or signal so that human eye can detect the device itself.



Basics of Automotive Lighting



Features

● Light sources

- All automotive lighting devices contain light sources
- In all cases, the light sources are powered with DC supply

● Optical elements

- To collect and redirect light emitted from the light sources for both functional and decorative purposes

● Mechanical elements

- To establish vehicle interface, thermal, water, and moisture management
- To provide environmental and operational protections

● Electronic elements

- To control lighting functions

Basics of Automotive Lighting



Regulated Performances

● Light output

- Luminous intensity level, min and max candela values
- Color (using chromaticity coordinates x, y)
- Visibility and size

● Type of devices

- Lamp locations on the vehicle
- Number of lamps

● Functionality

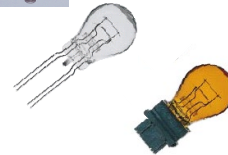
- RID: headlamp, fog lamp, front coring lamp
- SMD: DRL, stop, tail, parking, turn signal, backup, CHMSL, side marker
- Decorative lamps

SSL Used in Automotive Lighting

Light Sources Used in Automotive Lighting

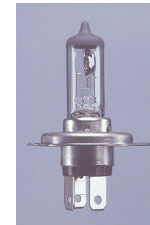
● Incandescent sources

- Miniature bulb
- Tungsten halogen bulb



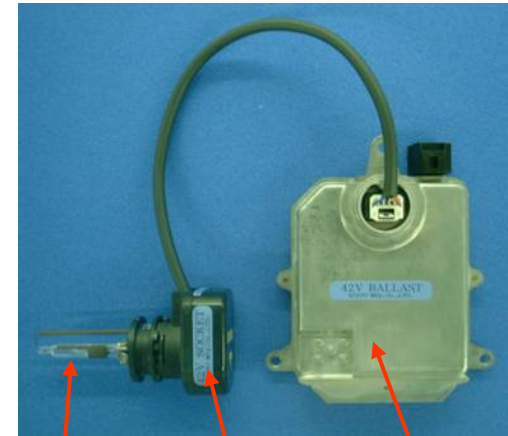
● Discharge sources

- HID
- Neon



● SSL sources

- LED
- OLED
- Laser diode



Burner Starter Ballast

SSL Used in Automotive Lighting

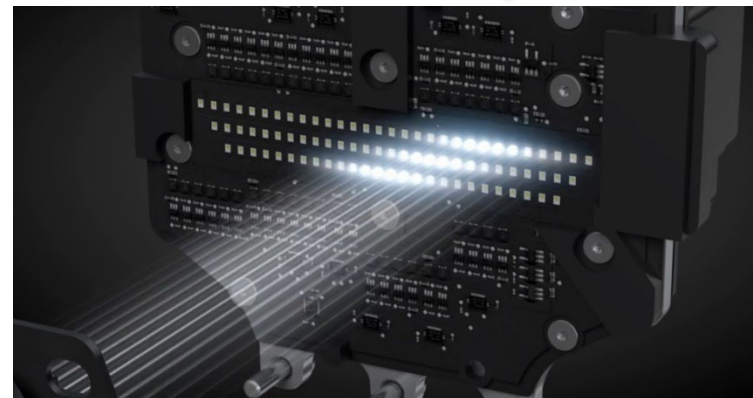
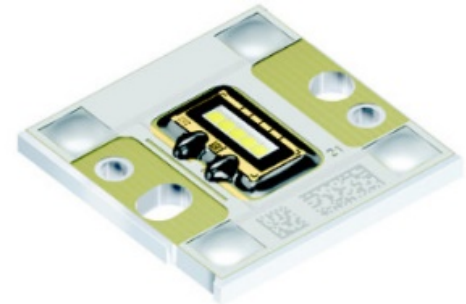
LEDs

● Automotive lighting, first adoption for LEDs

- Energy saving
- Longer life
- Vehicle styling
- Design benefits: compact size, design flexibility

● Type of LEDs

- Single color: red, yellow
- White
- Mini-LEDs



SSL Used in Automotive Lighting



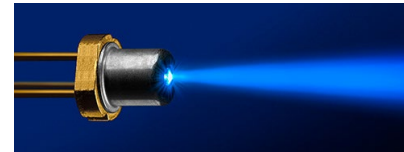
OLEDs

- **Purposes**
 - Design flexibility
 - Enhanced visual effects
- **Limitations**
 - Brightness



Laser Diodes

- **Advantages**
 - Higher luminous intensity (Etendue limitation for headlamp design)
 - Longer illumination range (300 meter or more)
- **Limitations**
 - Phosphor stability (high temperature)
 - Eye safety



Automotive Lighting Measurements

LED Measurements

Optical and electrical properties

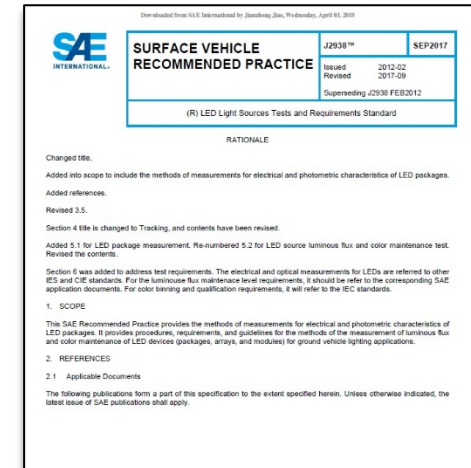
- IES LM-85

Lumine maintenance

- SAE J2938
- Lifetime of the light sources are based on average vehicle life and usage of each lamp
- Term of $L_{70}B_{10}$ is used in ECE (IEC 60810)

Table 4
Annual rates of use of lighting equipment, averages for all drivers

Function	Rate of Use (hours/year)
Backup	4.9
Daytime running lamp	309.2
High-beam headlamp	33.2
Low-beam headlamp	186.2
License plate	224.1
Parking	224.1
Side marker	224.1
Stop	102.7
Tail	224.1
Turn signal, left	26.2
Turn signal, right	20.6



UMTRI-2012-32

DECEMBER 2012

RATES OF USE OF VEHICLE LIGHTING EQUIPMENT: VARIATION AMONG DRIVERS

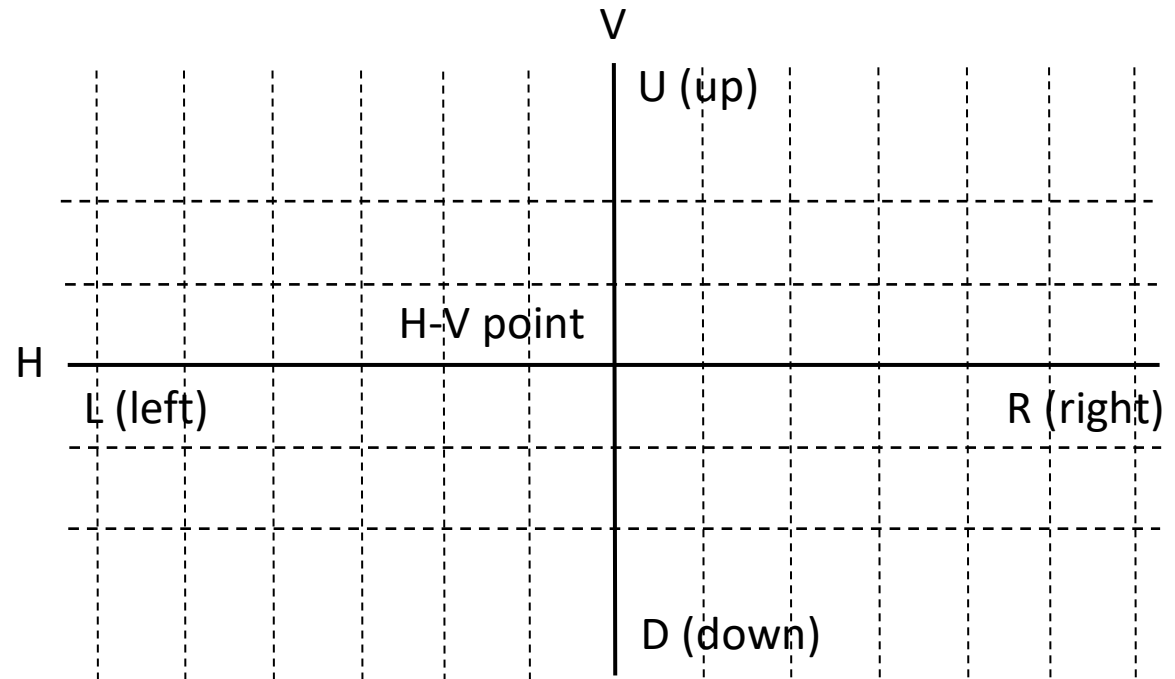
MICHAEL J. FLANNAGAN
MARY LYNN BUONAROSA



Automotive Lighting Measurements

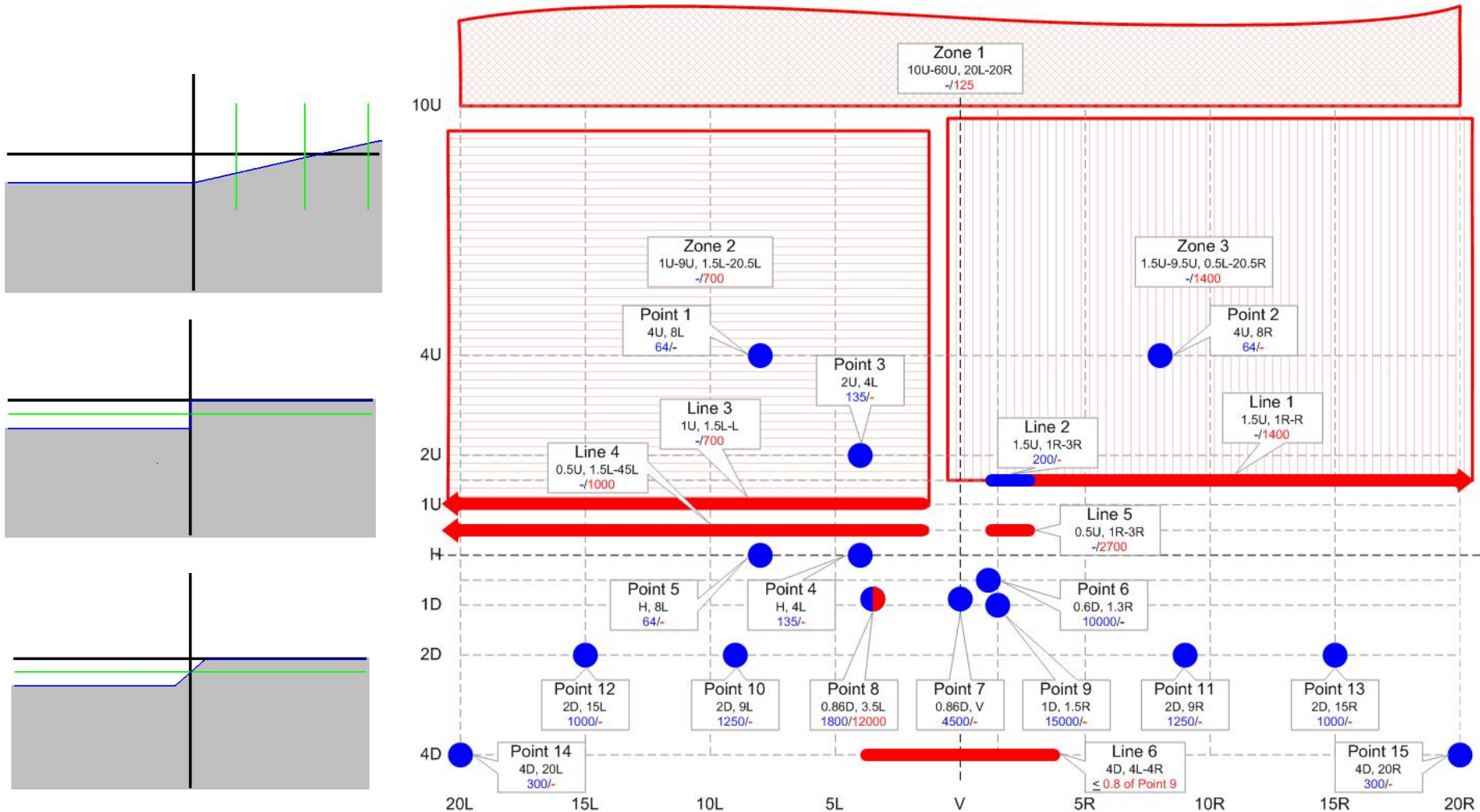
Lamp Measurements – RIDs

- **Luminous intensity angular distribution**
 - Minimum candela value: visibility
 - Maximum candela value: glare-light control
 - Intensity gradient: visually aimable



Automotive Lighting Measurements

RID Example: Low Beam Headlamp (SAE J1338)

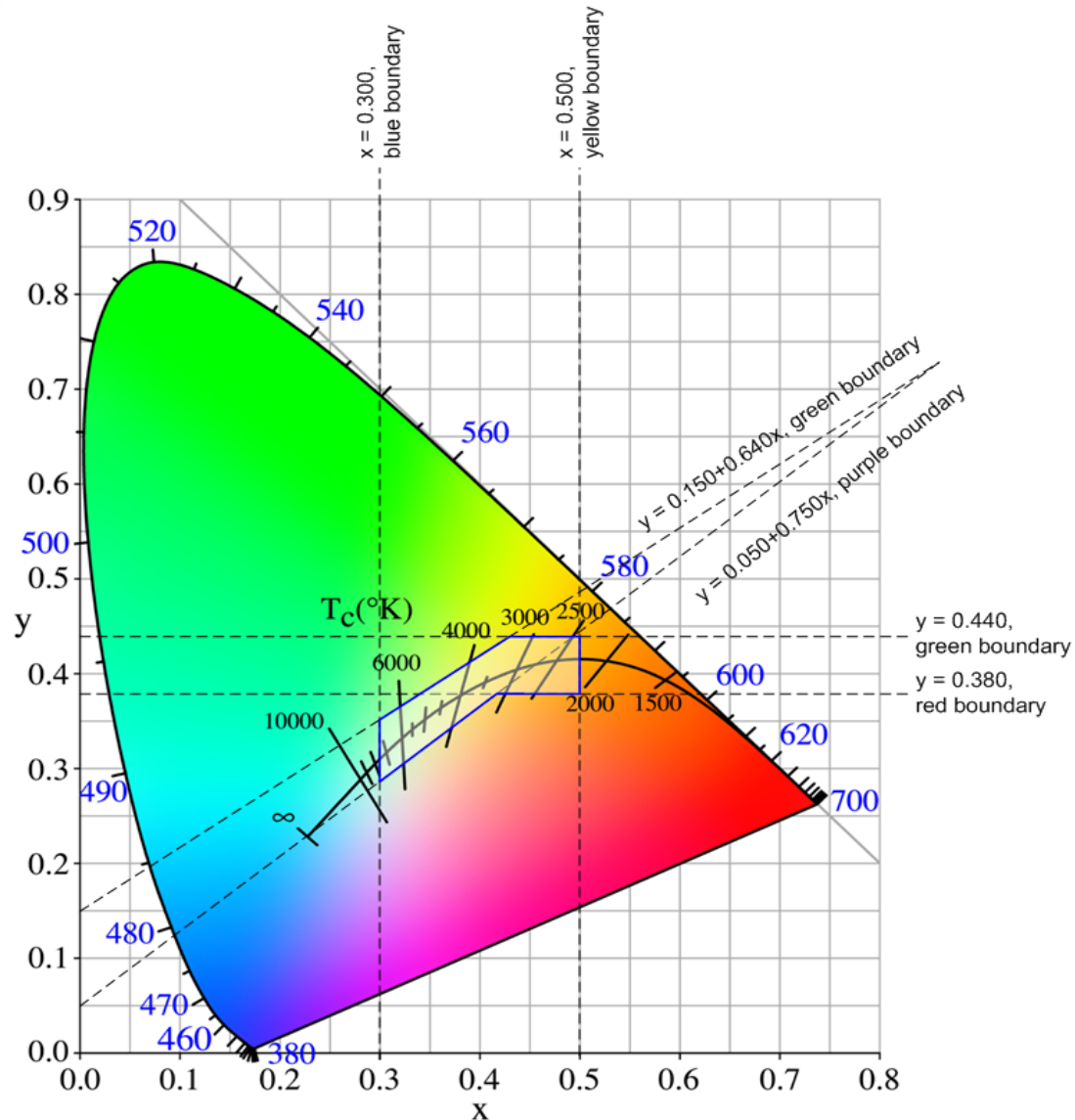


Automotive Lighting Measurements

Lamp Measurements – RIDs (cont.)

Color: white

- $x = 0.300$ (blue boundary)
- $x = 0.500$ (yellow boundary)
- $y = 0.150 + 0.640x$ (green boundary)
- $y = 0.050 + 0.750x$ (purple boundary)
- $y = 0.440$ (green boundary)
- $y = 0.380$ (red boundary)



Automotive Lighting Measurements



Lamp Measurements – SMDs

● Luminous intensity angular distribution

- Minimum candela value: visibility
- Maximum candela value: glare-light control
- Ratio between max and min values: dual-functional lamp conspicuity

● Visibility

- Visibility angle (measured in candela)
- Effective projected luminous lens area (EPLLA, measured in size)

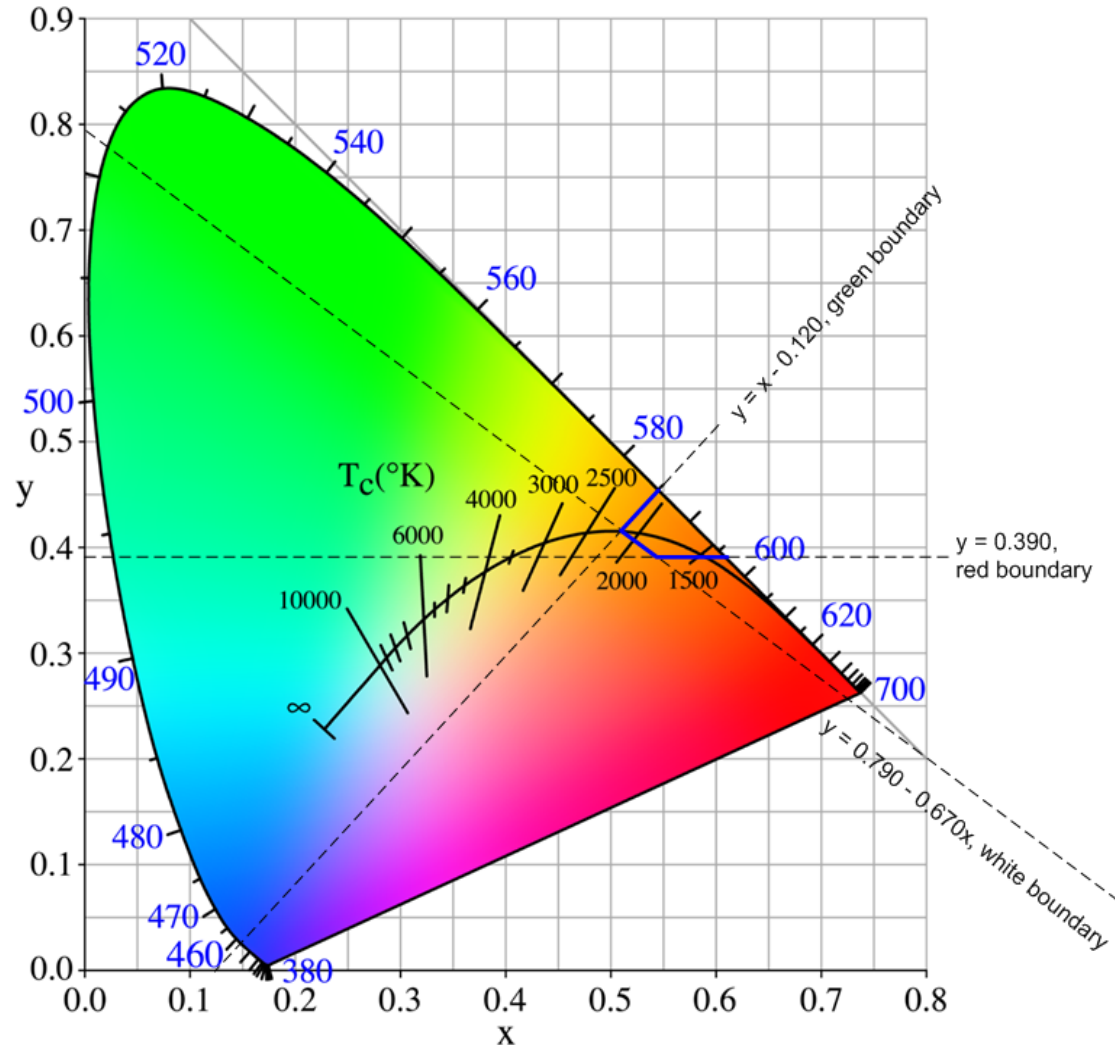
Automotive Lighting Measurements

Lamp

Measurements – SMDs (cont.)

● Color: yellow
(amber)

- $y = 0.390$ (red boundary)
- $y = 0.790 - 0.670x$ (white boundary)
- $y = x - 0.120$ (green boundary)

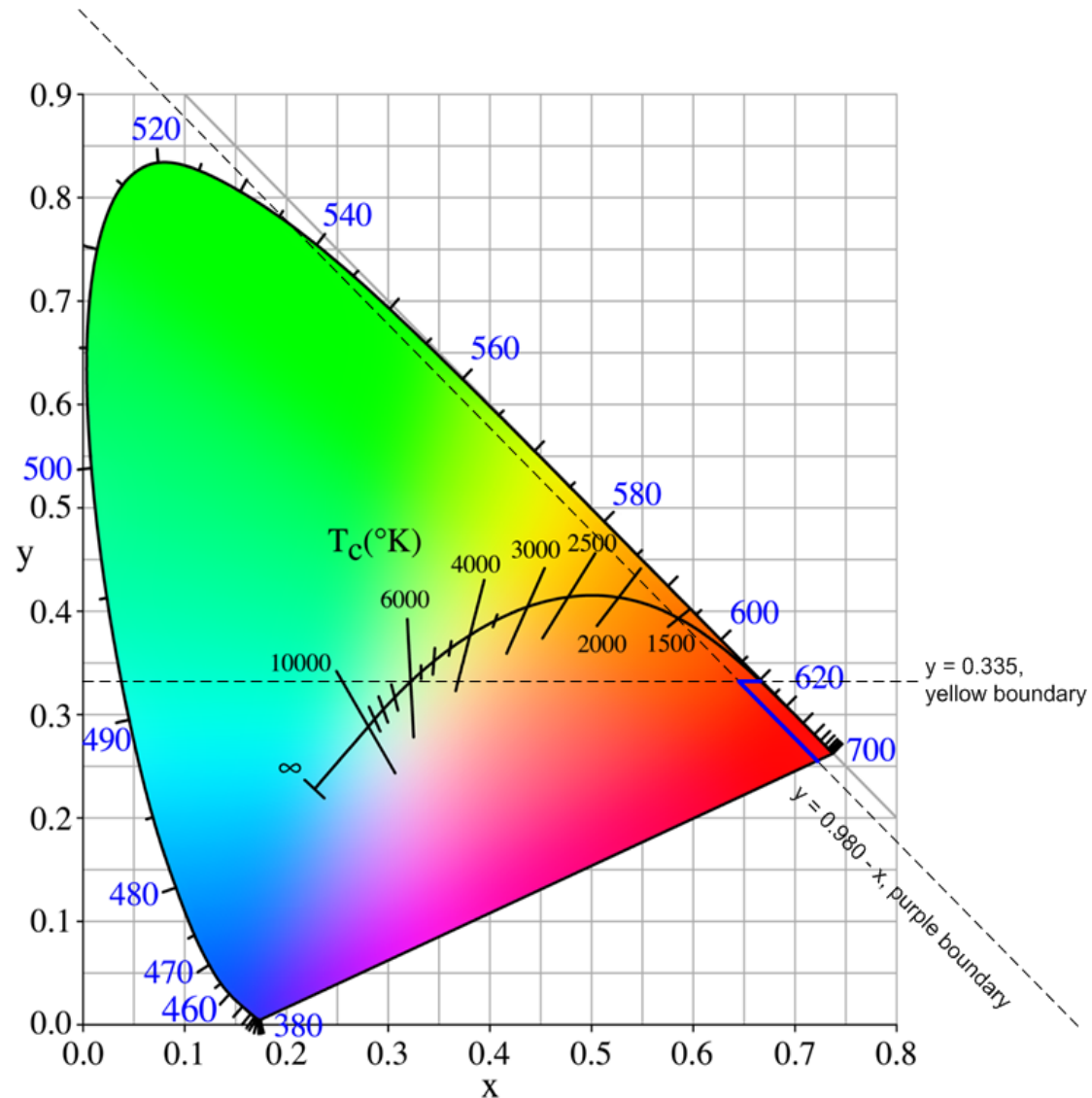


Automotive Lighting Measurements

Lamp Measurements – SMDs (cont.)

Color: red

- $y = 0.335$ (yellow boundary)
- $y = 0.980 - x$ (purple boundary)



Automotive Lighting Measurements

Specifics in Measuring LED Lamps

- **Comparison to traditional light sources**
 - Accurately rated (standard) bulbs must be used for photometry measurements
 - No standard LEDs

Automotive Lighting Measurements

Specifics in Measuring LED Lamps (cont.)

Standardize LED lamp thermal stability

- RID per SAE J2650:
- For lamps where LED contribute to the beam pattern, all applicable SAE standards photometry tests shall be conducted after the DUT is energized continuously for 30 minutes.
- For lamps where LED contribute to the beam pattern, test points or lines in Table 1 shall be measured within 1 minute after the DUT is energized.

Table 1 – Cold start photometry requirement

Function	Point and Line to Measure	Max Cd
Low Beam	1U – 1.5L-L	700
	0.5U – 1.5L-L	1000

Automotive Lighting Measurements

Specifics in Measuring LED Lamps (cont.)

● Standardize LED lamp thermal stability

- SMD per SAE J1889:
- Energize the DUT and record the max intensity H-V photometric value after 1 minute.
- Determine min photometric values by continuing to energize the DUT for 30 minutes, then record the photometric values at all the required test points.
- Determine the Max Ratio between the H-V reading at maximum intensity (often at 1 minute) divided by the H-V reading recorded before photometry test points are taken (e.g., 30 minutes).
- Determine the max photometric values by using the Max Ratio.

Performance-Based Measurements

Baseline of Automotive Lighting – Human Factors

- **Safety**

- Visibility
- Conspicuity

- **Driver's comfort**

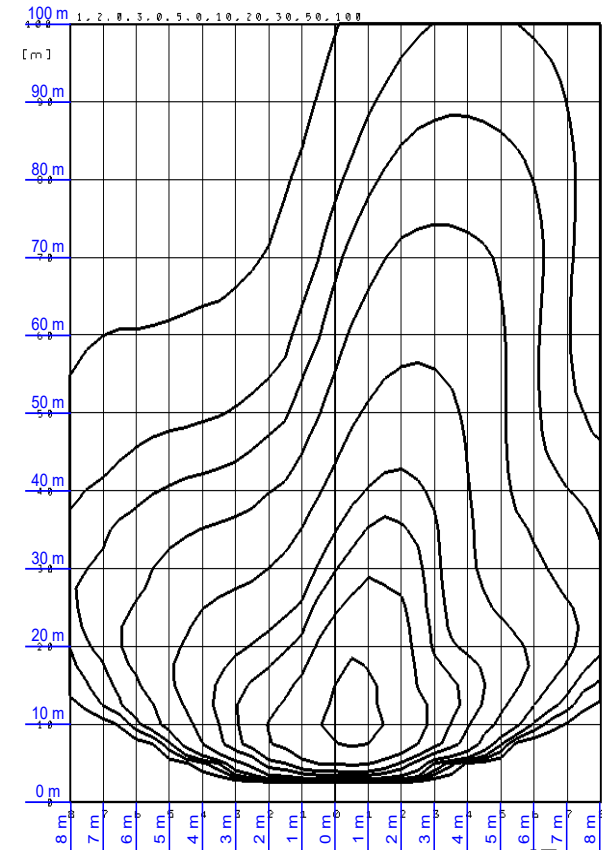
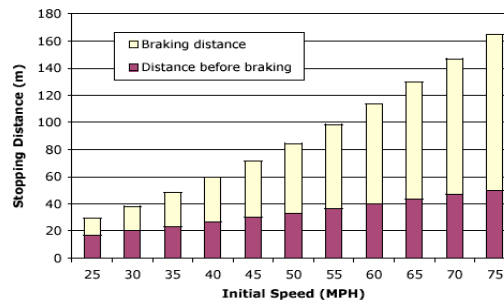
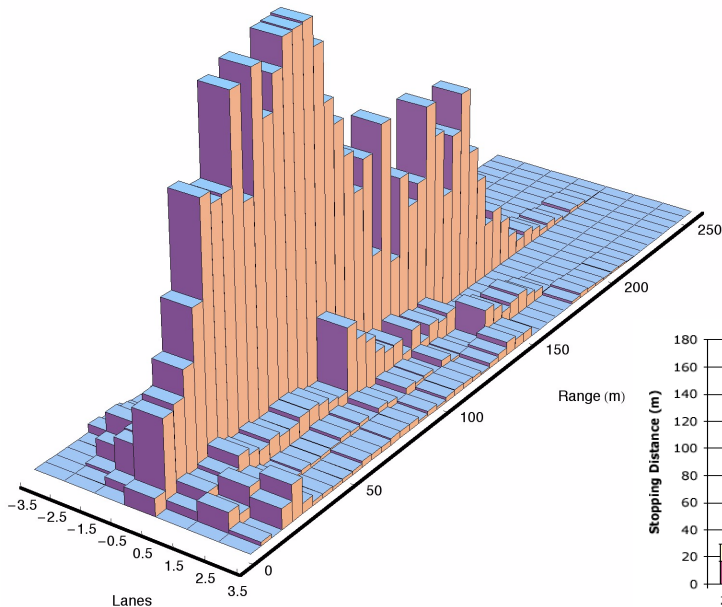
- Glare
- Headlamp performance rating system

Performance-Based Measurements

Baseline of Automotive Lighting – Human Factors (cont.)

Driver's visibility vs. headlamp illumination

- Detectivity (min lux value)
- Reaction time
- Stopping distance



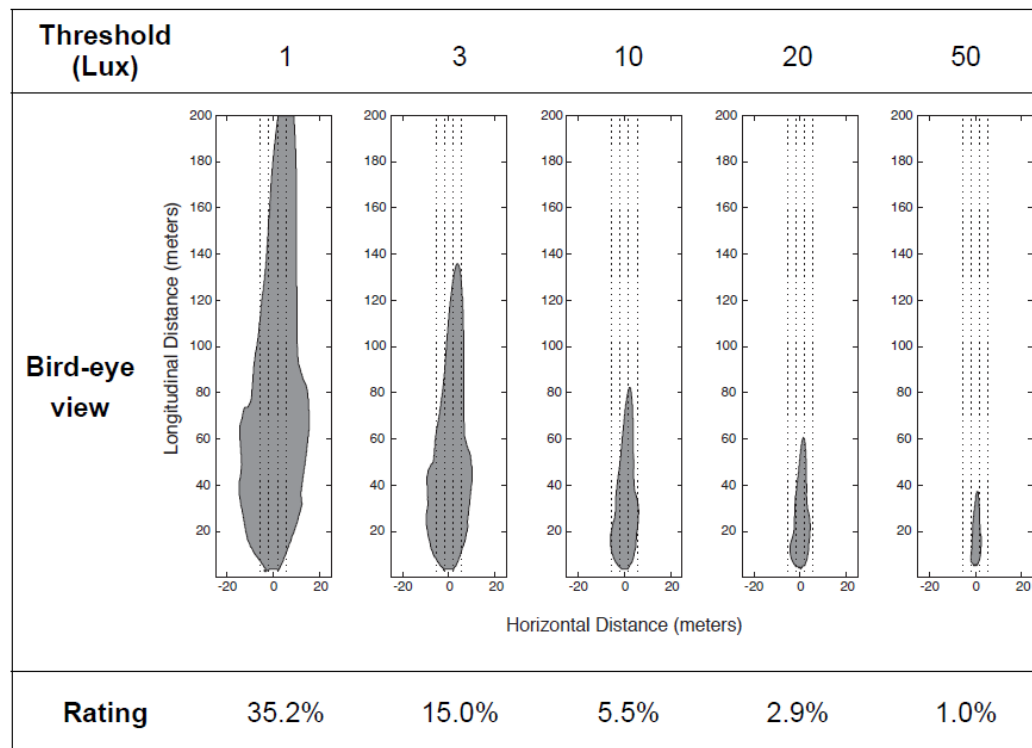
Performance-Based Measurements

Headlamp Performance Rating

● CHES Model

- Comprehensive Headlamp Environment Systems Simulation

Sample results of lux-area headlamp evaluation method.

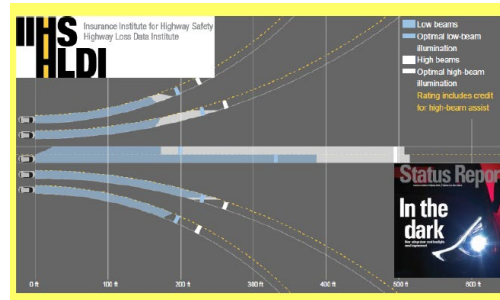


Performance-Based Measurements

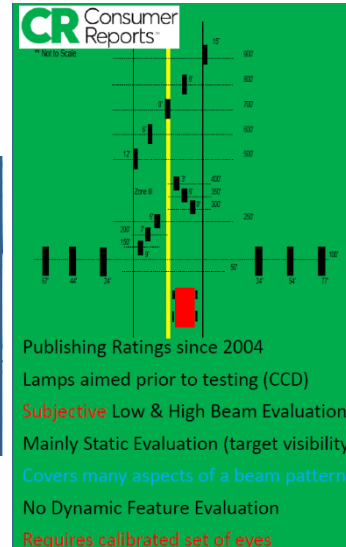
Headlamp Performance Rating (cont.)

Rating models

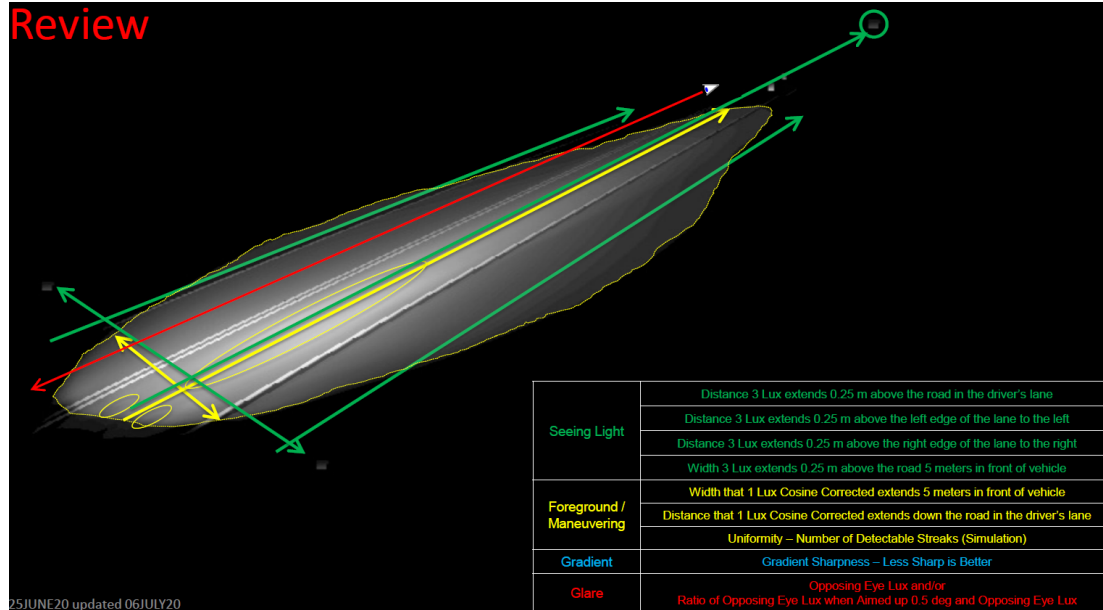
- Consumer Report
- IIHS
- US NCAP
- SAE



Press Releasing Ratings since 2016
 Lamp aim only checked (eye)
 Objective Low & High Beam Evaluation
 Dynamic Driving Evaluation (>5 lux)
ONLY focused on Down Road light
 Pushes legal limits of a beam pattern
 Includes AHB and AFS, not ADB
 Complex & Expensive Rating Method



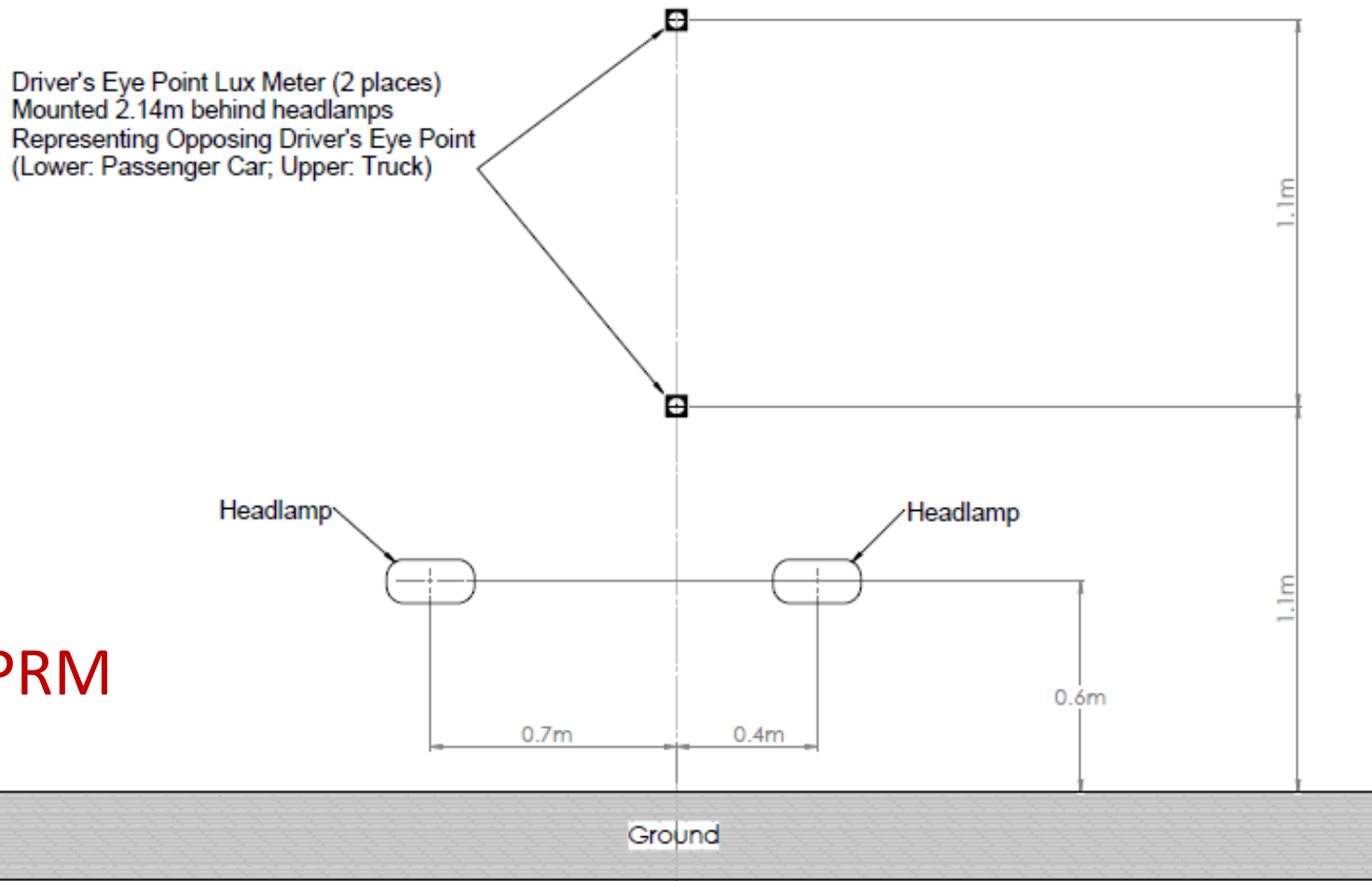
Review



Performance-Based Measurements

Adaptive Drive Beam (ADB) Measurements

- SAE J3069



- NHTSA NPRM



LEDs and Automotive Lighting Measurements

● Source level

- Lifetime is much shorter than the general lighting application
- Stability, reliability, and robustness are the higher priority

● Lamp level

- Luminous intensity angular distribution is the measurable
- Safety for visibility, or illuminous level on the road is the key consideration
- Performance rating system can be subjective but aimed to please customer



Thank You!

For further information, contact:
j_jiao@hotmail.com