Glare and Visibility in Automotive Lighting
Lighting Forum Geneva - Glare and Visibility
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Motivation

- **Questionnaire (567 Participants)**
  - Most relevant: country roads
  - Second: Urban Roads

- **Newer systems lead to more acceptance**

- **Nearly everyone wishes for more Light and better viewing Distance**

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### Participants enjoying Night Time Driving

- **Country:**
  - 42% 0% 20% 40% 60% 80% 100%

- **Urban:**
  - 31% 0% 20% 40% 60% 80% 100%

- **Motorway:**
  - 28% 0% 20% 40% 60% 80% 100%

### What are your fears when driving at night (2016)?

- Not seeing the road: 23%
- Objects not seen late: 43%
- Unsuitable driving: 51%
- Overlooked: 49%
- Being glared: 63%
- Wild animal crossing the road: 57%
- Motorway: 50%
- Urban: 62%
- Country: 42%

### Participants wishing for Better Light

- **Halogen:**
  - 85%
- **HID:**
  - 84%

- **Overall:**
  - 84%
## Investigating the Real Life Lighting Situation

<table>
<thead>
<tr>
<th></th>
<th>Distance</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Roads</td>
<td>20 %</td>
<td>38 %</td>
</tr>
<tr>
<td>Country Roads</td>
<td>42 %</td>
<td>36 %</td>
</tr>
<tr>
<td>Motorways</td>
<td>38 %</td>
<td>26 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>128 km</strong></td>
<td><strong>2h 35 min</strong></td>
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</tbody>
</table>
Glare Load Comparison
Day vs Night

- Significantly more Glare occurrences during the Night
  - 1800 Peaks during night
  - 510 Peaks during day

- Different Adaptation Level
  - 2 lx Night
  - $2 \cdot 10^3$ lx Day

- Different Light Sources
  - Headlamps vs „Natural Light“
Glare Load Comparison at Night
Different Road Types

- Low Intensity (No Glare) in Cities and Motorways
  - High Adaptation in Urban Areas
  - Low Peaks on Motorways

- Strong Peaks, High Glare on Country Roads
  - Oncoming Traffic
Reasons for High Glare Load

- Insufficient headlamp aiming
  - Only about 20% of all vehicles are properly aimed
  - Kosmas: TU Darmstadt 2013 & IFAL 2015 & Internal Documents 2018

- Headlamp Cleaning
  - Only mandatory for systems with a luminous flux > 2000 lm
  - Left out of vehicles with LED
  - Only cleans Low Beam
  - Could influence both viewing distance and glare negatively

- Headlamp Levelling
  - Vehicle dynamics influence the position of the cut-off line
  - Only static requirements

More Glare

Less Detection
Field-Test
Influence of dirt on the headlamp light distribution

Measurements under real traffic conditions
- Alps or towards Norway with uncertain weather / road conditions
  - Low reproducibility
  - Measurements in public road traffic

Measurements on a testing area under semi realistic conditions
- Setup of the measurement in a fixed location
  - Same testing conditions for each day
  - Controlled environment
  - High frequency of measurements possible

→ The testing area’s advantages outweigh
Testing circuit

Test Circuit
length: approx. 410 m
width: approx. 3.5 m

Measurement
place direct at the
test circuit
Data Visualization
Clean Headlamp vs. Dirty Headlamp
Results
Light Distribution: influence of dirt

**Average Luminance above the Cut-Off (Glare)**
- **clean**: 12 cd/m² (2.27 lx at 25 m)
- **dirty**:
  - 1.2 km: 30 cd/m² (5.69 lx at 25 m)
  - 9.6 km: 70 cd/m² (13.29 lx at 25 m)

→ **Higher Glare with dirty Headlamps**
Results
Light Distribution: influence of dirt

Average Luminance below the Cut-Off (Detection)
- **clean**: 155 cd/m² (29.4 lx at 25 m)
- **dirty**:
  - 9.6 km: 80 cd/m² (15.2 lx at 25 m)

→ Lower Detection Distances with dirty Headlamps
Reasons for High Glare Load

- **Insufficient headlamp aiming**
  - Only about 20% of all vehicles are properly aimed
  - Kosmas TU Darmstadt 2013 & IFAL 2015 & Internal Documents 2018

- **Headlamp Cleaning**
  - Only mandatory for systems with a luminous flux > 2000 lm
  - Left out of vehicles with LED
  - Only cleans Low Beam
  - Does influence both viewing distance and glare negatively

- **Headlamp Levelling**
  - Vehicle dynamics influence the position of the cut-off line
  - Only static requirements
Headlamp Levelling

- Vehicle Pitch → Change the absolute position of the Cut-Off Line
  - Load
  - Chassis
  - Driving Dynamics
  - Roadgeometry and -surface

- Comparison of
  - HID Headlamps with dynamic Levelling
  - Halogen System without Levelling
Test Setup
Headlamp Levelling

Measurement Vehicle 1
- GPS
- Photometer
→ Acceleration of Test Vehicle

Test Vehicle
- Halogen und HID Headlamps
- Levelling: activated und deactivated

Measurement Vehicle 2
- GPS
- Photometer
→ Glare for constant driving
Comparison of the Light Distributions
Halogen vs. HID

- Lower Luminous Flux
- Narrower Light Distribution

Same vehicle in use → Same vehicle dynamics

Halogen-HID

Halogen < 2000 lm

Xenon > 2000 lm
Pitch Angles during Acceleration

- When accelerating, pitch angles of up to 1°
  - Potentially high illuminance values for oncoming traffic

How does the levelling system influence the illuminance for oncoming traffic?
Comparison of Illuminance
HID vs. Halogen

- Dynamic levelling compensates the pitch angles for acceleration
- Without dynamic levelling high illuminance values are recorded during acceleration
- For constant velocity identical values
- Halogen headlamps have identical values as HID for acceleration

\[ \rightarrow \text{Reminder: Same Vehicle – different Headlamp} \]
\[ \rightarrow \text{Luminous flux not a suitable factor for levelling} \]
Glare - Detection

What are your fears when driving at night (2016)?

- beeing glared: 63%
- wild animal crossing the road: 57%
- pedestrian or cyclist overlooked: 53%
- unsuitable driving: 51%
- objects seen too late: 43%
- not see the road: 23%
- fatigue: 19%
- hardly estimate distances: 18%
Detection Test
Viewing Distances with different Headlamp Intensities

Measured Light Distributions:
- Standard Low Beam
- High Beam (75 kcd)
- High Beam + Laser (215 kcd)

Test Vehicle:
- GPS-Position
- GPS-Time

Illuminance
Luminance
GPS-Position
GPS-Time
Detection Test
Viewing Distances with different Headlamp Intensities

- Significant differences between Intensities
- Mean Detection Distances:
  - 48.0 m Low Beam, 103.2 m High Beam, 167.4 m High Beam + Laser Modul
- Elderly drivers – 15% lower detection distances
## Results

Detection probability at various stopping distances

<table>
<thead>
<tr>
<th>Distance in m</th>
<th>Passing Beam</th>
<th>Driving Beam</th>
<th>Laser Booster</th>
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<tbody>
<tr>
<td>55</td>
<td>27.72 %</td>
<td>97.05 %</td>
<td>99.91 %</td>
</tr>
<tr>
<td>80</td>
<td>1.18 %</td>
<td>85.92 %</td>
<td>99.60 %</td>
</tr>
<tr>
<td>110</td>
<td>0.00 %</td>
<td>44.64 %</td>
<td>97.57 %</td>
</tr>
<tr>
<td>160</td>
<td>0.00 %</td>
<td>2.69 %</td>
<td>65.93 %</td>
</tr>
</tbody>
</table>

→ Low Beam is not suitable!
Summary

- Detection dependant on luminous Intensity
  - Low Beam should only be used if necessary
  - High beam needs to deliver a certain amount
  - Assistent systems should be used widely

- Dirt influences the light distribution
  - More glare (up to 5x higher illuminance)
  - Less detection (0.5x lower illuminance)
  - Decreases the already critical distances

- Levelling can help prevent more glare
  - Vehicle dynamics influence potential glare
  - Headlamp types are not the crucial factor
Thank you for your attention
Measurement Setup

**Side-view**

- Luminance Camera
- Aperture for stray light
- Screen
- Distance: = 5m

**Top view**

- Aperture 1 to cover one headlamp
- Luminance Camera
- Aperture 2 for stray light
- Screen
Research so far


- Glare-Illuminance:
  at first it increases with amount of dirt on the HL (scattered Light) and decreases then

\[ \begin{align*}
\text{Above cut-off line} & \\
\text{Below cut-off line} & \\
\end{align*} \]

\[ \begin{align*}
\text{Illuminance E} & \\
\text{Amount of dirt} & \\
\end{align*} \]

\[ \begin{align*}
\text{Higher Glare} & \\
\text{Lower Visibility} & \\
\end{align*} \]

→ Frequent measurements in dependency of distance or time
Data Analysis
finding the Cut-off

- Luminous picture of clean headlamp
- Finding the cut-off line through image processing
- Region of Interest:
  - Horizontal: ± 4°
  - Vertical: ± 1°

Region **Above** Cut-off → Glare-Region
Region **Below** Cut-off → Visibility-Region