Improving Visibility with DLP® Headlights

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Automakers are looking for ways to improve visibility during nighttime driving. DLP® automotive technology for headlights can improve visibility and provide support for additional applications.

At a glance

This paper highlights how DLP technology is innovating within the latest trends in the automotive industry including futuristic headlight applications.

1 Adaptive driving beam headlight benefits

Enabling the segmentation of the high-beam headlight field of view to maximize the amount of light projected on the right sections of the road.

2 An example of headlight field

Showcasing the versatility of DLP technology for high-resolution headlights and how DMDs can enhance a vehicle's lighting system.

3 Futuristic headlight applications

Structured light, traffic sign dimming, weather detection are just a few new applications where DLP technology can add value and improve vehicle functionality.

Headlights are designed to illuminate the road ahead, along with any potential hazards. Basic headlights typically employ two modules: a low-beam base light and a manual on/off high beam. Drivers rarely encounter situations necessitating the use of high-beam headlights, however, and end up using this option sparingly.

Recently, there has been a big push in the automotive lighting industry to improve both vehicle headlight functionality and driver visibility, which has led to the development of adaptive driving beam (ADB) headlights. An ADB system automatically controls the entire headlight, including high beams, enabling drivers to focus on the road and stop toggling their high beams on or off based on lighting conditions and the presence of oncoming vehicles.

The benefits of ADB and resolution

The goal of an ADB automotive exterior lighting system is to improve road safety by maximizing the amount of light projected onto the road without affecting oncoming drivers. For vehicles without high-beam field-of-view (FOV) segmentation also known as pixelated high beam lights, ADB system functionality includes turning high beams on and off automatically. New technologies, including DLP technology for automotive applications, enable segmentation of the high-beam headlight FOV – in other words, turning portions of the high-beam headlight on or off individually.

For example, if a high-beam headlight has 12 segments, only a few of these segments need to be turned off to prevent drivers of oncoming vehicles from experiencing glare. Other segments can still illuminate the road and will result in more light than vehicles without an ADB system. **Figure 1** gives an example of a nighttime driving situation where a driver is approaching an oncoming vehicle, a traffic sign, and a pothole in the road. The driver's vehicle is not equipped with an ADB system, so only the vehicle's base light illuminates the road. **Figure 2** represents the same driving scenario as Figure 1, except this time the driver's vehicle is equipped with a 12-pixel segmented ADB system. The segmented ADB system is illustrated with red boxes to highlight each pixel's illuminated area in the high beam FOV.

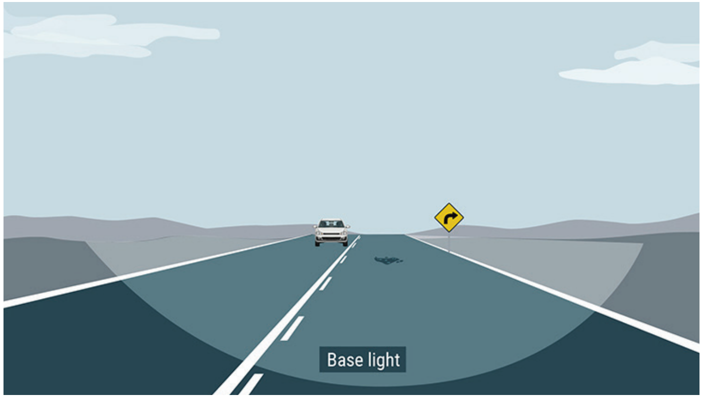

Figure 1. *Headlight FOV with only a base light module.*

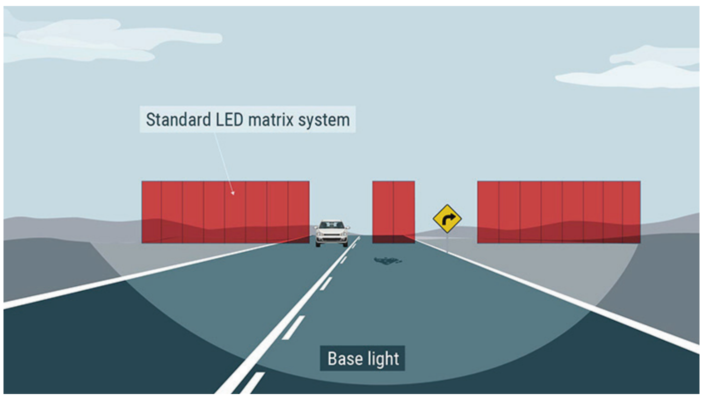

Figure 2. *Headlight FOV with a background 12-pixel matrix. Each pixel is illustrated with the red segment in the high beam FOV.*

You can see from Figures 1 and 2 that more segments in the ADB system enable more light from the high-beam FOV to illuminate the road. This relationship holds true as the number of segments increases by orders of magnitude over a constant FOV – because as segments get smaller, the ADB system can leave more segments on without illuminating other vehicles and creating a glare for other drivers.

In addition to more light on the road, an additional benefit of an increased number of segments is smoother movement of masked regions, which can reduce driver distractions, from large areas of the high beam FOV quickly switching on and off. Masked regions in an ADB system are the areas of the FOV not illuminated by the high-beam module that prevent glare from an oncoming driver and the vehicle's ADAS system. In Figure 2, the masked regions are the areas missing an LED segment, illustrated by the red boxes, in the high beam FOV, which are the areas around the oncoming vehicle (to prevent glare for the oncoming driver) and traffic sign (to prevent reflected light from glaring on the front camera of the ADAS system).

Vehicle original equipment manufacturers (OEMs) and Tier-1 headlight suppliers have consistently discussed the need to increase ADB resolution to illuminate more details on the road and reduce driver distractions from masked region movement. The [DLP5533A-Q1](DLP5533A-Q1) high-resolution headlight digital micromirror device (DMD) offers the highest available ADB resolution, with 1.3 million individually addressable micromirrors. Each micromirror on the DLP5533A-Q1 can correspond to a segment in the high-beam FOV, enabling the ADB system to function with minimal light "waste" and create very precise masking regions.

Another benefit of the DLP technology for automotive applications is the ability to discretely move a masked region in the high-beam FOV. With higher solution ADB systems and smoother transitions of masked regions in the high beam FOV, drivers may find the ADB system to be more natural and less distracting than an ADB system with few high beam segments. OEMs and Tier-1 headlight suppliers have explored moving the DMD's projection region in the headlight FOV to enable applications other than high-resolution ADB headlights.

The headlight FOV matrix and the DMD

In standard vehicles without ADB systems, two modules separate the low and high-beam regions. The standard high-beam module covers a FOV of 40 degrees by 10 degrees per headlight. These modules are aligned to cover a total vehicle high-beam FOV of 80 degrees by 10 degrees. Elementary ADB systems employ a limited number of pixels (usually 12 per headlight, for a total of 24) to control the entire 80-degree-by-10-degree high-beam space. Typically, these ADB systems have no control in the vertical region, meaning that the segment covers all 10 degrees in the vertical direction. With an increase in resolution, ADB systems have the ability to provide vertical control, with a 2D pixel matrix for high beam segmentation, and maximize the amount of light projected onto the road. Figure 2 depicted an example ADB system with only 12 segments per headlight and no vertical control of the high beam segments, as only a 1D matrix is shown. The area above and below the oncoming vehicle and the area around the traffic sign could have been illuminated with higher resolution, potentially revealing objects or oncoming obstacles.

OEMs and Tier-1 headlight suppliers have asked for methods to provide additional resolution for ADB systems, especially in the center of the high-beam FOV. The center of the high-beam FOV is critical to maximize light, as road hazards typically lay directly in front of the vehicle. Current automotive headlight high-beam module illumination profiles typically have a small area of peak luminance near the center.

Figure 3 shows a standard high-beam illumination profile and supports the idea that high resolution is only necessary in the center of the high-beam FOV. Having high resolution toward the edges of the high-beam FOV can exponentially add system complexity and cost, without providing an appropriate functionality gain. Because of this fact, Tier-1 headlight suppliers have designed a new headlight with a third module designed to provide high resolution only in the center of the vehicle's FOV. DLP automotive technology can enable a cost-effective high-resolution region to directly address this new headlight architecture, while making it easy for Tier-1 headlight suppliers to create a modular design and support multiple vehicle trims.

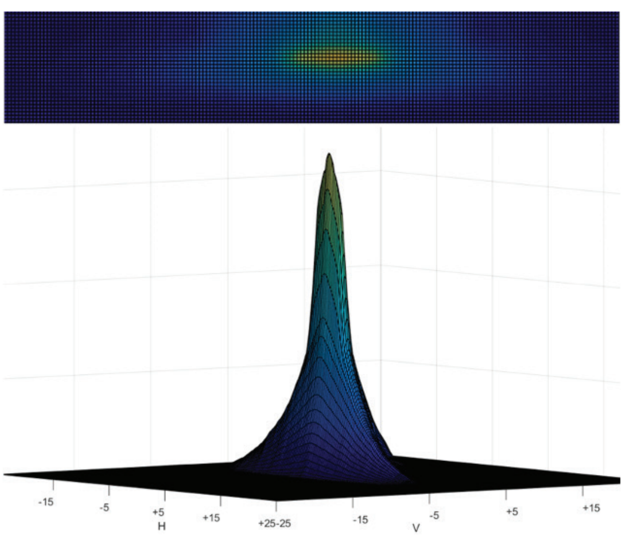

***Figure 3**. Typical high-beam illumination profile with a high-center peak.*

The DLP5533A-Q1 DMD is optimized to support a module that covers a FOV of around 14 degrees by 7 degrees; each headlight typically uses one of these modules. But two DLP5533A-Q1 modules, one per headlight, result in a 28-degree-by-7-degree high-resolution region for the vehicle's FOV.

Figure 4 shows the example headlight FOV breakdown from Figure 2 with a high-resolution region, and a case where a DLP headlight module increases the amount of light projected on the road by illuminating the areas above and below the vehicle (which are not illuminated by the background high-beam matrix module).

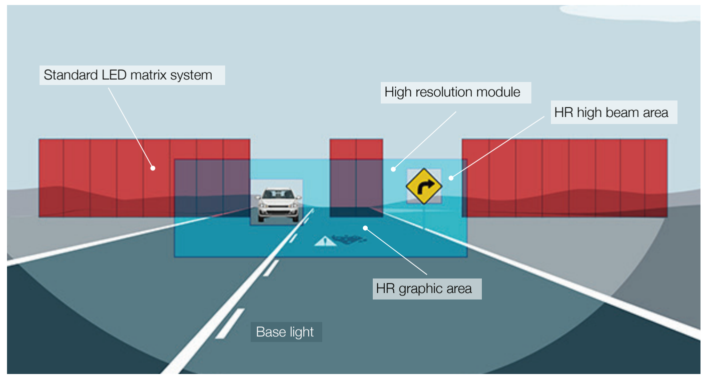

***Figure 4.** DLP headlight FOV breakdown.*

In Figure 4, the 28-degree-by-7-degree high-resolution region is placed to cover space in both the low-and high-beam FOV. This straddling enables the DLP headlight module to project high-resolution symbols on the load in the "HR graphic area" in the low beam FOV in addition to providing ADB support (high-resolution area in the high-beam FOV). The DLP5533A-Q1 is a great fit for symbol projection because of the resolution needed to create comprehendible symbols (such as a right turn arrow indicating that the driver needs to turn right). The relationship between resolution and the clarity of symbols projected from a headlight is amplified compared to standard projection displays due to the orientation of the vehicle's headlights. Because the headlights are not projecting on a surface perpendicular to the projection source, the projected symbols can easily become stretched out and become incomprehensible to the driver without enough angular resolution.

Figure 5 shows the difference in projected symbols between angular resolutions of 0.05 degrees per pixel, which can be achieved with a 20,000-pixel matrix dedicated for symbol projection, and 0.01 degrees per pixel, which can be achieved with the low-beam region of a DLP5533A-Q1 high-resolution headlight module. These angular resolutions correspond to about 12 lines and 49 lines, respectively, when projecting a 2-m tall image from 10 m away.

0.05 degree/pixel 0.013 degree/pixel

Figure 5*. A right turn signal with 10-m notification at different vertical resolutions.*

The symbol-projection region, highlighted as the HR graphic area in Figure 4, can help drivers navigate to their destination, alert them to potential hazardous road conditions, or project the vehicle's intended path. Symbol projection not only provides an additional method of vehicle communication, but can be also be a differentiating factor for vehicle features and driving experiences. Symbol projection shows the versatility of DLP technology for high-resolution headlights and how it can extend the value proposition of a vehicle's lighting system.

Futuristic headlight applications

Although DLP technology greatly improves ADB systems and enables symbol projection with its high resolution, there are other ways that DLP technology-based headlights can add value to vehicles by expanding applications to improve advanced driver assistance system (ADAS) functionality. These futuristic applications can include structured light, which could help next-generation ADAS to better detect and identify objects and obstacles in the road; traffic-sign dimming, to prevent front camera glare; and weather detection, to remind drivers of potentially hazardous road conditions.

Structured light. A DMD can switch states extremely fast on the order of microseconds – enabling the DLP headlight module to display single-bit patterns for a very short period of time. When these single-bit patterns are synchronized to the vehicle's front camera refresh rate, the DLP headlight module can project patterns designed to function as a depth sensor while being unnoticed by the driver. This application is known as structured light. The ADAS processor uses the front camera to capture the response to the pattern and determine whether any objects are in the path of the vehicle. If the ADAS system detects any debris or potholes, it can alert the driver of the hazard through the symbol-projection feature. This is depicted in Figure 4, our original driving scenario, and **Figure 6**, where the DLP headlight and front camera system recognize and alert the driver to a pothole.

Figure 6*. DLP headlights working with the ADAS camera systems to detect and alert drivers to objects in the road.*

Besides pothole and debris detection, structured light can also improve an active suspension system's performance at night. Many active suspension systems struggle with nighttime performance because of poor system visibility, but DLP headlights can greatly improve the performance of active suspension systems.

Traffic-sign dimming. OEM and Tier 1s have expressed a desire to move the ADAS front camera sensor near or inside the headlights. One downfall of this new location is that the ADAS camera systems can suffer reduced performance at night near traffic signs. Traffic signs can interfere with ADAS front camera performance and accuracy at night if the adaptive headlights reflect light directly back to the light source. When a camera has a light shined directly onto its lens, the camera sensor "blooms" or oversaturates and completely washes out the image. This washed out image prevents any real world data from reaching the ADAS system and is thus unable to alert the driver to potential hazards. Using the DLP headlight module's high resolution, an ADAS system can create a highly efficient mask and turn off the light directed at the traffic sign. This enables the vehicles front end camera ADAS system to function properly and the driver can better comprehend the traffic sign. Traffic-sign dimming is a must-have feature for ADB when used on city streets and highways, as traffic signs are prevalent on these types of roads. **Figure 7** depicts a DLP headlight dimming a traffic sign but illuminating a child trying to cross the road.

Figure 7*. DLP headlights highlight a child attempting to cross the street while dimming the crosswalk sign to reduce glare.*

- **Weather detection**. High-resolution headlamps can be used to help detect the weather condition during nighttime driving. Some vehicles can detect weather with just a camera during the day, but it's a challenge at night due to poor lighting conditions. With high-resolution headlights, the vehicle can increase the intensity of light to a specific area to help improve camera visibility. By enabling the vehicle's ADAS front camera system to detect weather conditions at night, the vehicle can automatically enable safety features or configurations to better handle hazardous conditions including fog and icy roads.

Conclusion

Although the DLP5533A-Q1 DMD was designed to improve ADB resolution and help vehicles maximize the amount of light on the road, this device's 1.3 million micromirrors are enabling new applications. Symbol projection can help drivers keep their eyes on the road by projecting navigation symbols in front of the car and help the vehicle "communicate" with surrounding vehicles by projecting an intended path. Structured light could enable features within vehicles that can warn drivers of upcoming hazards like potholes and objects in the road. Traffic-sign dimming can help reduce front camera glare and support proper ADAS functionality. Weather detection can help keep the driver's eyes on the road during the most critical times. DLP high-resolution headlights will continue to meet the needs of OEMs and tier-1 headlight suppliers while providing a platform for designers to innovate and develop new features.