Efficient high resolution headlight systems with TI DLP® technology

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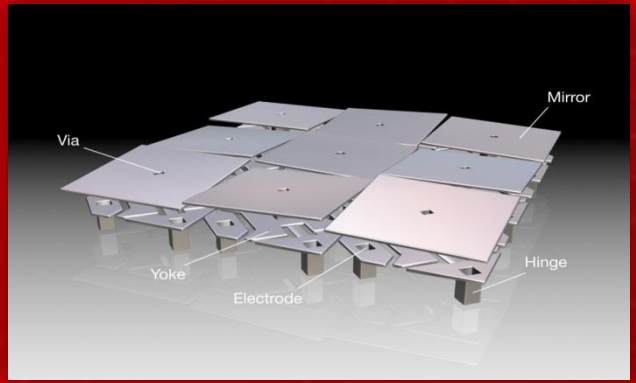
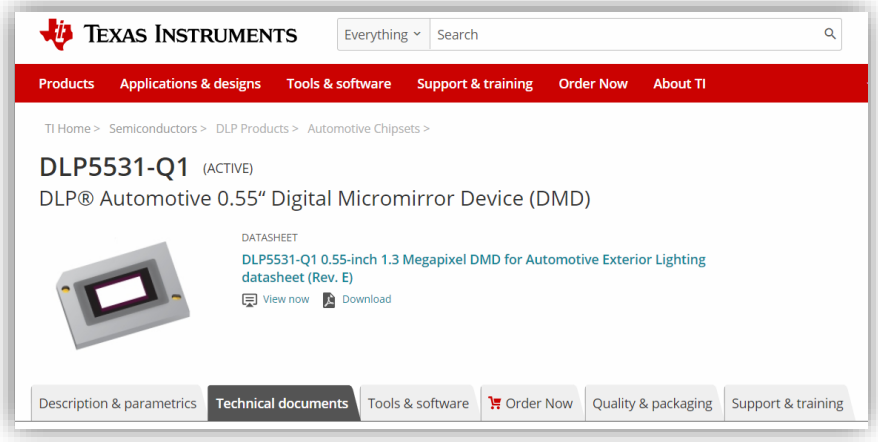
Engineering Manager



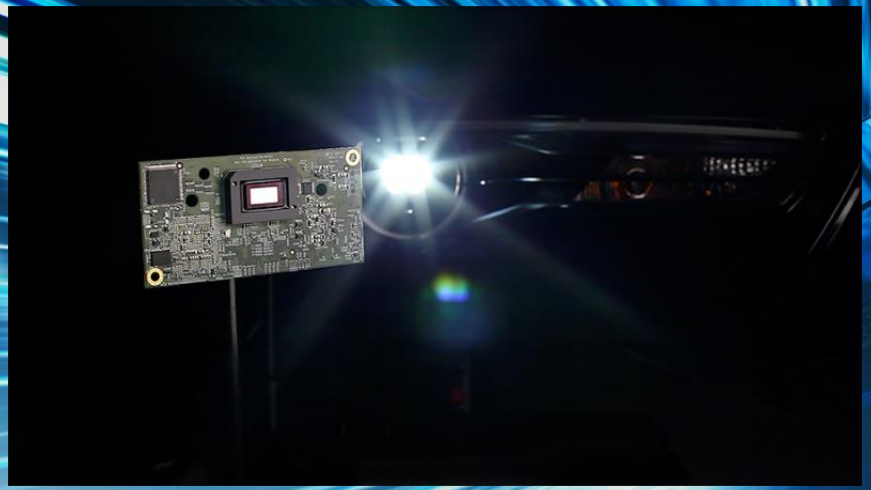
Topics for today

- Benefits of a digital micromirror device (DMD) for automotive lighting applications
- A case for high resolution
- Efficiency and throughput analysis
- Future improvements
- Additional applications for communicating with light



ti.com/dlpautomotive

Introducing sophisticated adaptive driving beam headlight technology



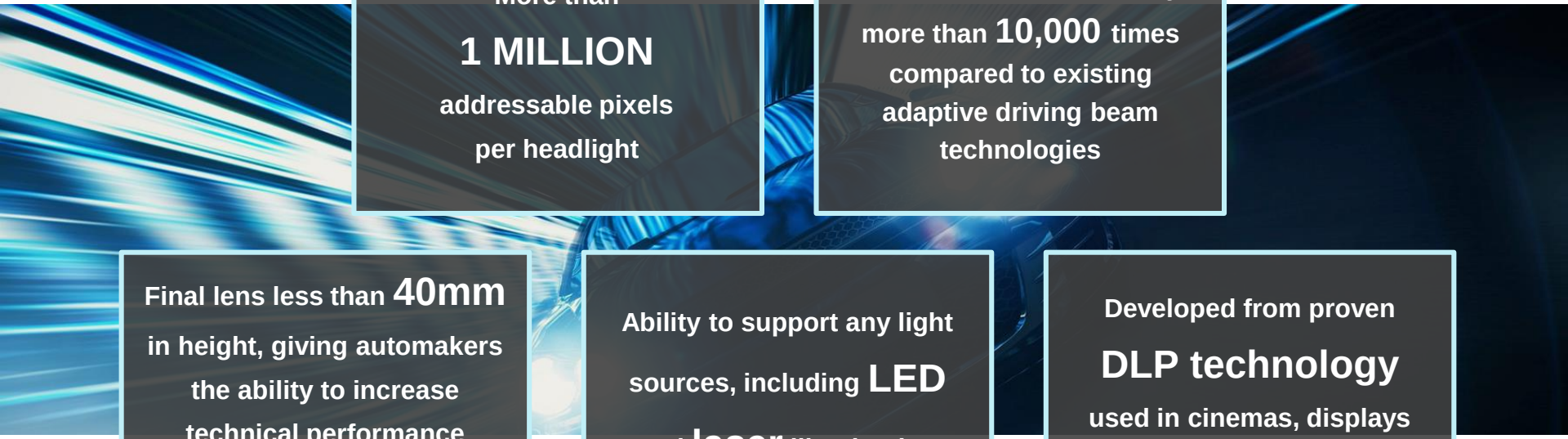
High brightness, high performance

State-of-the-art technology

More than one million addressable pixels per headlight

ENHANCES DRIVER VISIBILITY, MINIMIZE GLARE, AND COMMUNICATE WITH LIGHT

Highest resolution exterior automotive lighting solution available



More than **1 MILLION** addressable pixels per headlight

Extends the resolution by more than **10,000** times compared to existing adaptive driving beam technologies

Final lens less than **40mm** in height, giving automakers the ability to increase technical performance without sacrificing style

Ability to support any light sources, including **LED** and **laser** illumination

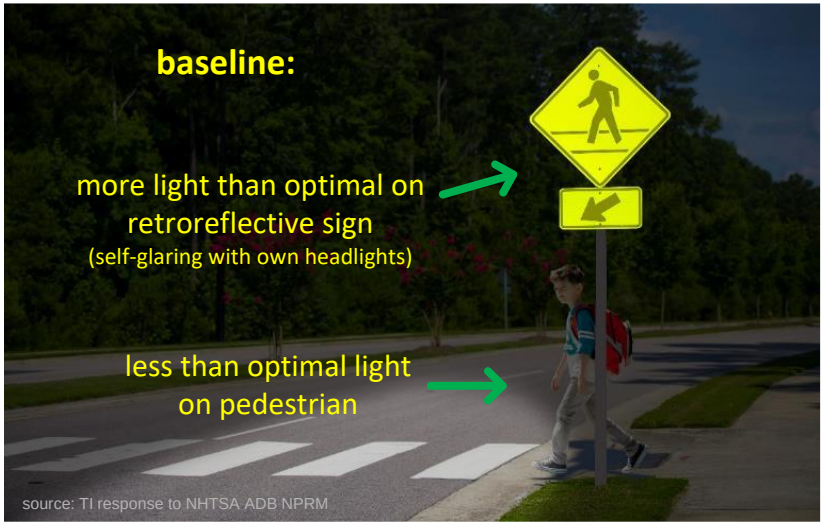
Developed from proven **DLP technology** used in cinemas, displays and in automotive

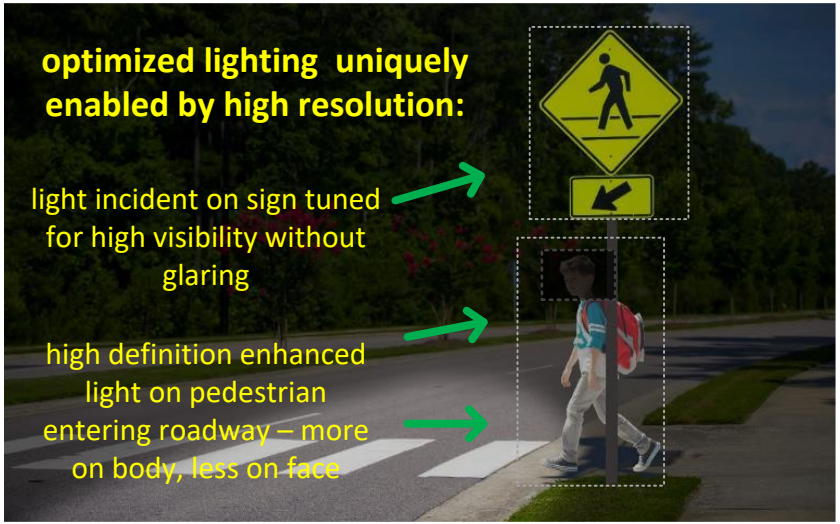
Only automotive technology on the market that is both fully programmable and highest resolution available

Programmable lighting technology

Transforms headlight systems into communication channels by projecting relevant information on the road that can enhance communication between drivers, pedestrians and other vehicles

Flexibility to create custom, fully programmable headlight systems that reinvent how vehicles and drivers interact





Adaptive driving beam (ADB) solution

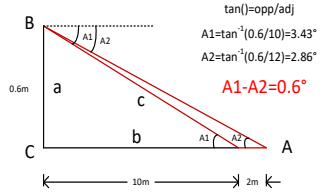
Allows automakers and Tier-1 suppliers to control every one of the more than one million pixels in each headlight to maximize brightness and minimize glaring for oncoming traffic or reflection from retroreflective traffic signs

On-road Symbol Resolution Requirements

Used with Permission: Daimler AG
https://www.mercedes-benz.com/en/mercedes-benz/innovation/digital-light-headlamps-in-hd-quality

On-road Symbol Requirements

Assuming a 14x7 degree system...



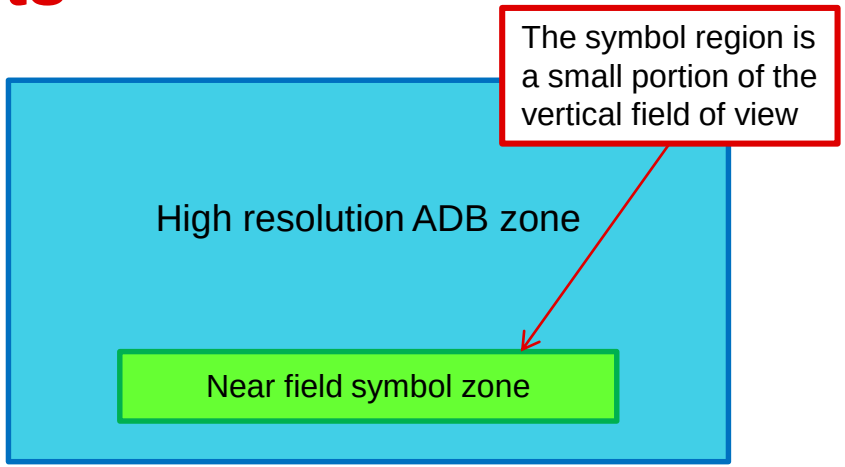
Resolution Examples:

0.05 degree/pixel

0.013 degree/pixel

for a 2m symbol at 10m → symbol is a mere 0.6° tall

Very high resolution is required for on-road symbols



On-road symbol zone is ~8-10% of imager vertical lines

(0.6° / 7°)*576 lines = **49 lines (good)**

for a 100 line system -> **8 lines (bad)**

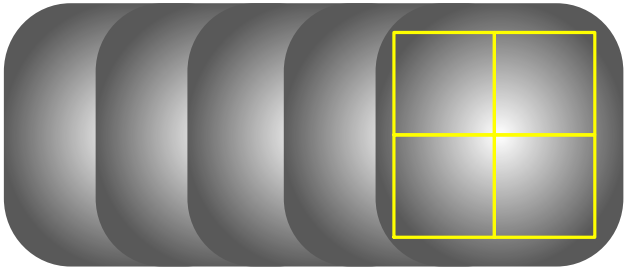
(a 40,000 pixel system is generally ~100 lines)

Displacement Resolution vs. Display Resolution

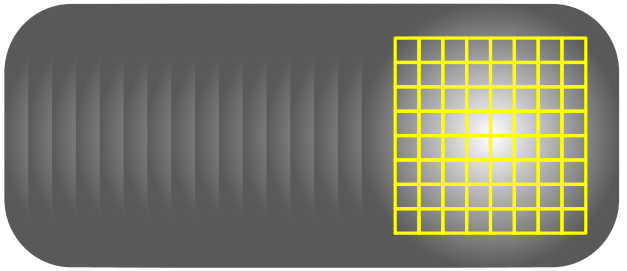
One benefit of high resolution for ADB is smooth mask opening motion

Higher resolution = smoother

Even with optics resolution lower than the imager resolution, the high resolution of the imager produces useful benefits – smooth motion, smoother object edges, pixel-free appearance



imager resolution ~ optics resolution: large steps

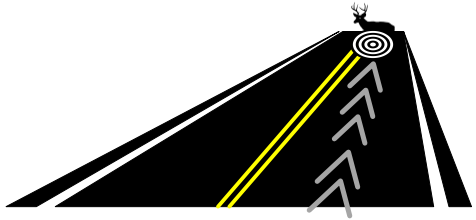


imager resolution >> optics resolution: small steps

High resolution enables smooth object motion

Long Range High Resolution Applications

number of stripes on 1m tall object		degree / pixel			
		0.2	0.1	0.05	0.02
distance (m)	25	5	11	22	57
	50	2	5	11	28
	100	1	2	5	14
	150	0	1	3	9



DMD case: 10°/576 lines = 0.017 degree / pixel in vertical, better than 0.02°/pixel

0.1° per pixel supports useful patterns out to only about 50m

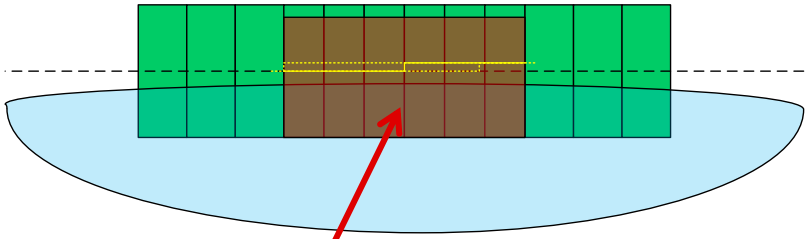
Better than 0.1° per pixel resolution is required to pattern at long range

High resolution DMD module + low resolution LED matrix

This combination makes a lot of sense – headlight efficacy is a mix of matrix and DMD module

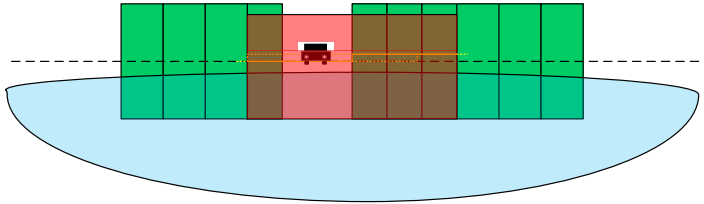
0.4*24lm/W + 0.6*45lm/W[1] = **36.6lm/W**

[1] E.-O. Rosenhahn, “New Systems for Safety and Comfort, Improvement by High Resolution Flexibility,” SIA Vision, Paris, 2018.



Total high beam is a very effective combination of DLP technology and LED matrix base light:

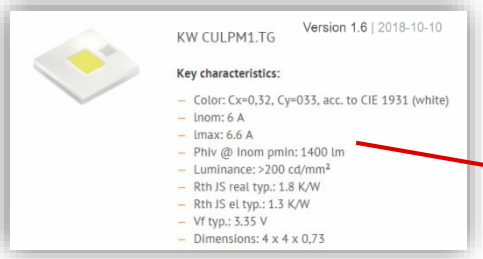
system ***performance*** is set by DMD module



system ***efficiency*** enhanced by low cost matrix base light

“All pixels on” efficacy comparison

DLP technology + Osram Oslon Boost HX



Source: https://www.osram.com/os/ecat/OSLON%C2%AE%20Boost%20HX%20KW%20CULPM1.TG/com/en/class_pim_web_catalog_103489/global/prd_pim_device_2190861/

Collimator	96%
Collection eff.	75%
DMD	66%
Projection Lens	92%
Cover Glas	90%
Total	39%

Table 2: Optical on axis efficiency transmissions and contributors for efficiency.

6	A	If
3.35	V	Vf
20.1	W	power
1400	lm	lumens
69.7	lm/W	device efficacy
0.9	W/W	e/e conversion eff.
62.7	lm/W	Oslon+PS efficacy
0.39		optical efficiency
24.4	lm/W	DLP efficacy, baseline

Osram EVIYOS Gen2:

Optics Eff:	33%

Punch

Field o View	H	19,0 °	V	5,0 °
	H/pix:	0,1 °	V/pix:	0,1 °
Pixels:	H	190	V	50
Hot Spot Target:	168 lx@25m	Pixel Number:		9500
Pixel Size in 25m:	H	0,04 m		0,04 m
Pixel Flux in 25m:		0,320 lm		

Table 6: Calculation of the performance values for the EVIYOS idea for the base and punch area

With the hybrid integration of the driver and latest UX:3 LED technology efficacies of 65 lm/W including current regulating drivers can be expected. This promises to place the power consumption of a full beam of 1200 lm on the road (3600lm at the source) at just 56 electrical Watts.

65	lm/W	device efficacy
0.33		optical efficiency
21.5	lm/W	system efficacy

Information sourced from Oslon Boost HX datasheet and 2018 SIA Vision paper:

Illumination vs. Visualization in Headlamps: Way towards HD light source requirements

S. Groetsch[1], J. Reill[1], M. Schwind[1], S. Haneder[1], U. Hiller[1]

[1]: Osram Opto Semiconductors GmbH, Leibnizstr. 4, D-930555 Regensburg, Germany

Impact of ADB masking on efficacy

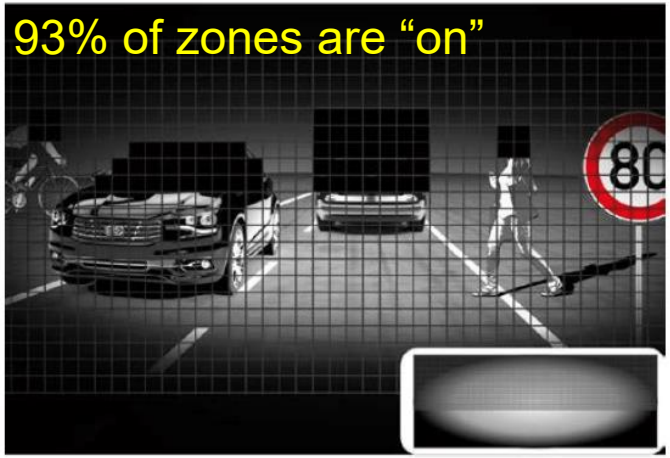


Figure 6: Elements from Figure 2 illuminated with a .two dimensional pixel matrix

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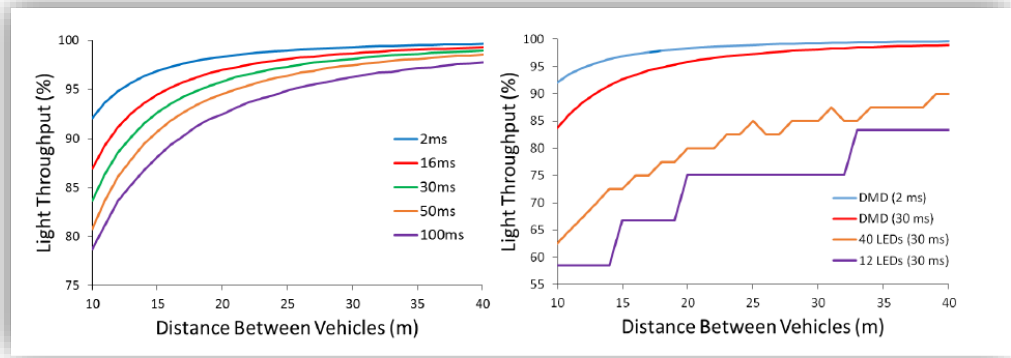
This ~90% “throughput” case (or ratio of on pixels to total over time) **is expected** for a *DMD* ADB system:



see: **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]

[1] Carnegie Mellon University, Pittsburgh, PA USA
[2] Intel Research, Pittsburgh, PA USA

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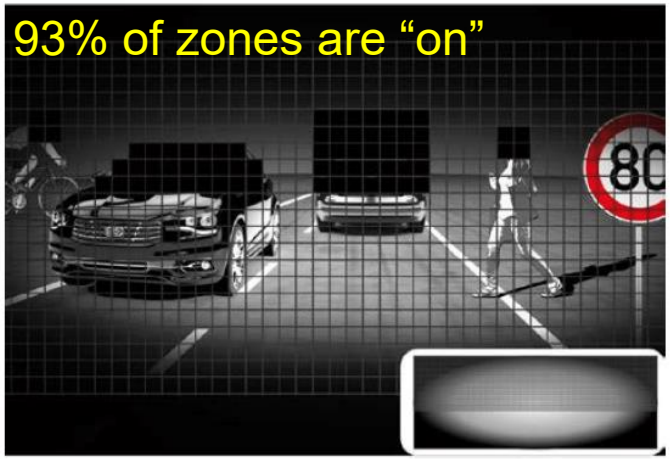

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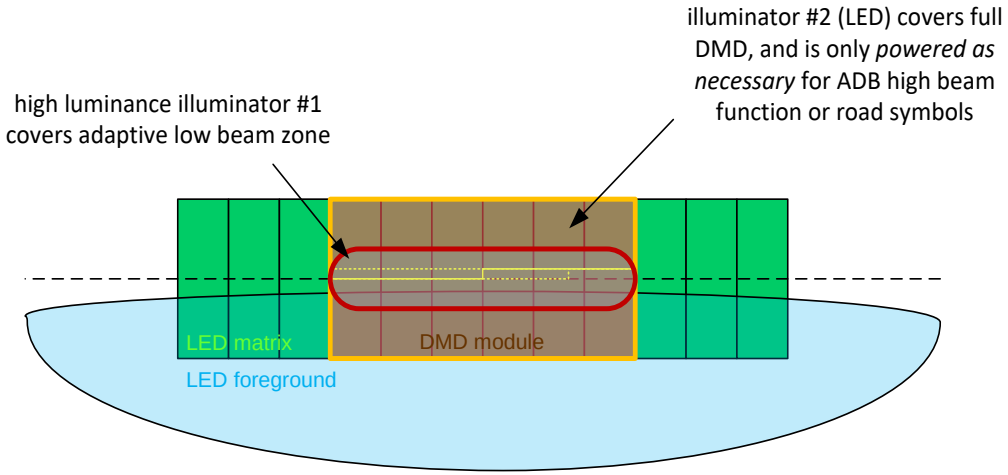
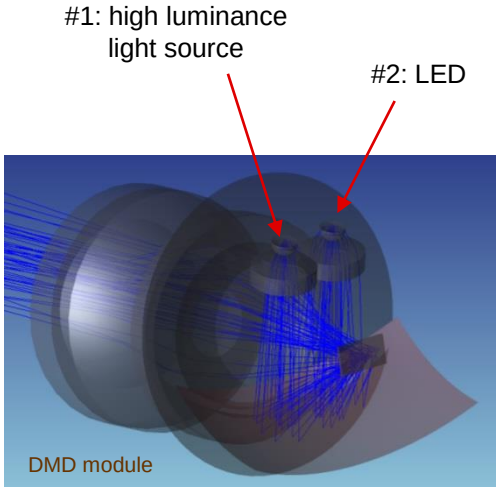
880	zones	total (~40x22)
65	zones	are off…
815	zones	are on…
0.93		subtractive loss factor
24.4	lm/W	DLP efficacy, baseline
22.6	**lm/W**	**DLP efficacy, adjusted**
21.5	**lm/W**	**micro LED efficacy**

The net impact on total efficacy from “subtractive” ADB has been greatly exaggerated – with *high resolution*, very little *subtracting* actually happens in real-world situations

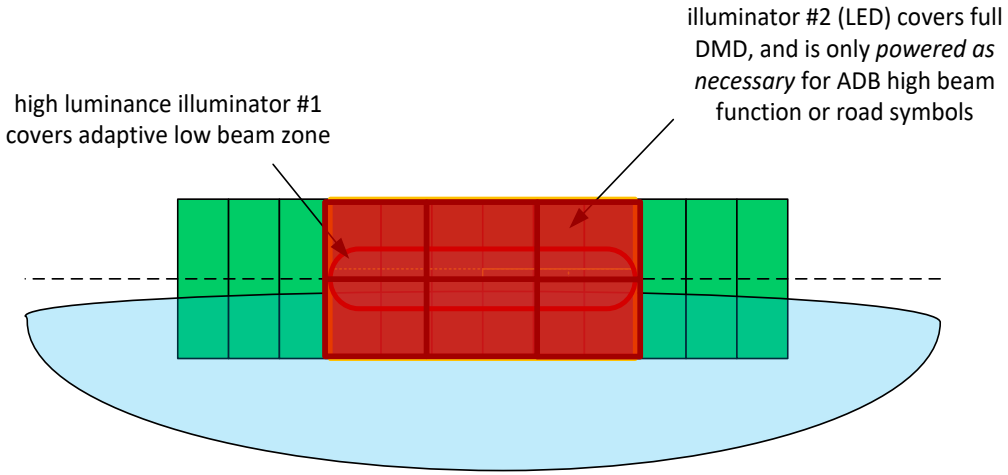
Future improvements – mix of high luminance source and LED improves low beam-only efficiency

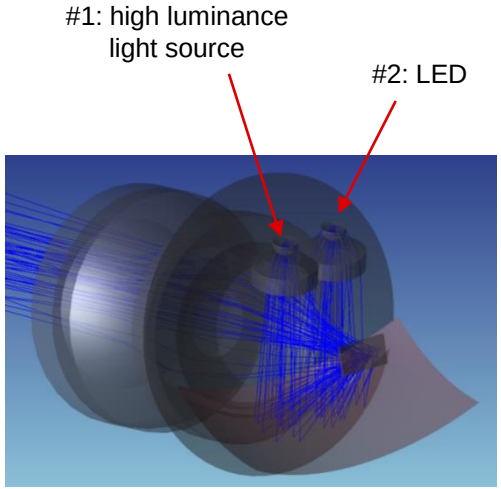




During low beam only operation - majority of illuminator power directed to cut line region where most of the light is needed, the broader coverage LED operated at reduced current

Future improvements – mild segmentation of LED





Modest segmentation of LED source further enhances situational power consumption, allowing for up/down left/right source power optimization – high density micro-LED technology is not required, a few dimming zones is enough

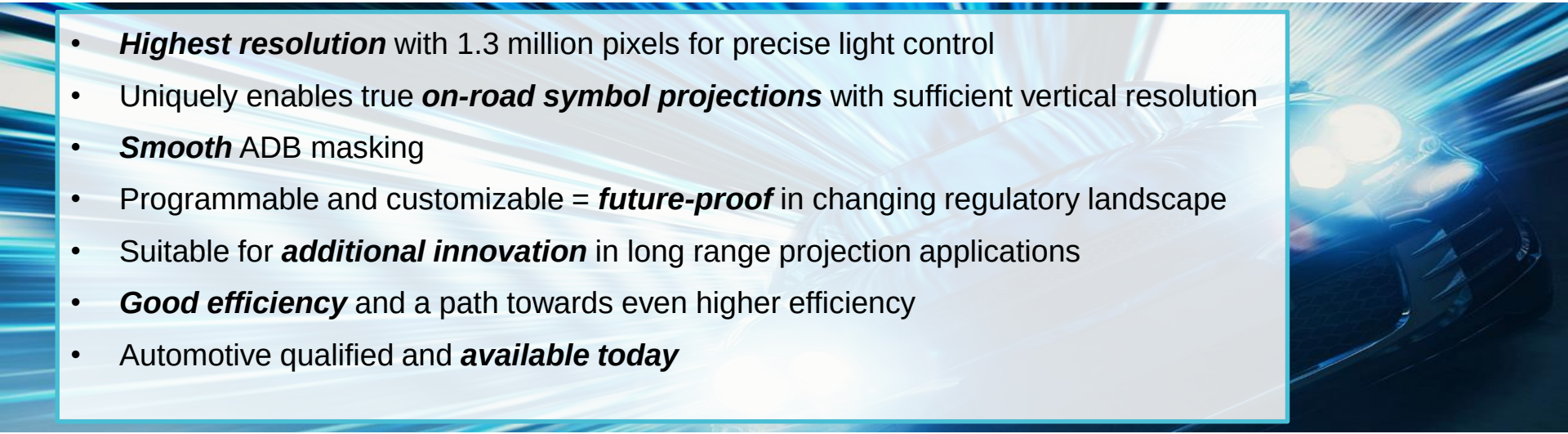
Surprise and delight with DLP Technology

- Puddle lights capable of animation and full color
- Develop unique welcome sequences or messaging
- Reinforce branding or ease communication
- Many install locations:
  - Side-mirror, vehicle corners, rocker panel, etc.

Surprise and delight with DLP Technology

Photos from TI Exhibition Booth at CES 2019

DLP Technology offers compelling solutions in automotive lighting



- ***Highest resolution*** with 1.3 million pixels for precise light control
- Uniquely enables true ***on-road symbol projections*** with sufficient vertical resolution
- ***Smooth*** ADB masking
- Programmable and customizable = ***future-proof*** in changing regulatory landscape
- Suitable for ***additional innovation*** in long range projection applications
- ***Good efficiency*** and a path towards even higher efficiency
- Automotive qualified and ***available today***

ENHANCES DRIVER VISIBILITY, MINIMIZE GLARE, AND COMMUNICATE WITH LIGHT