

HOE for Automotive Applications



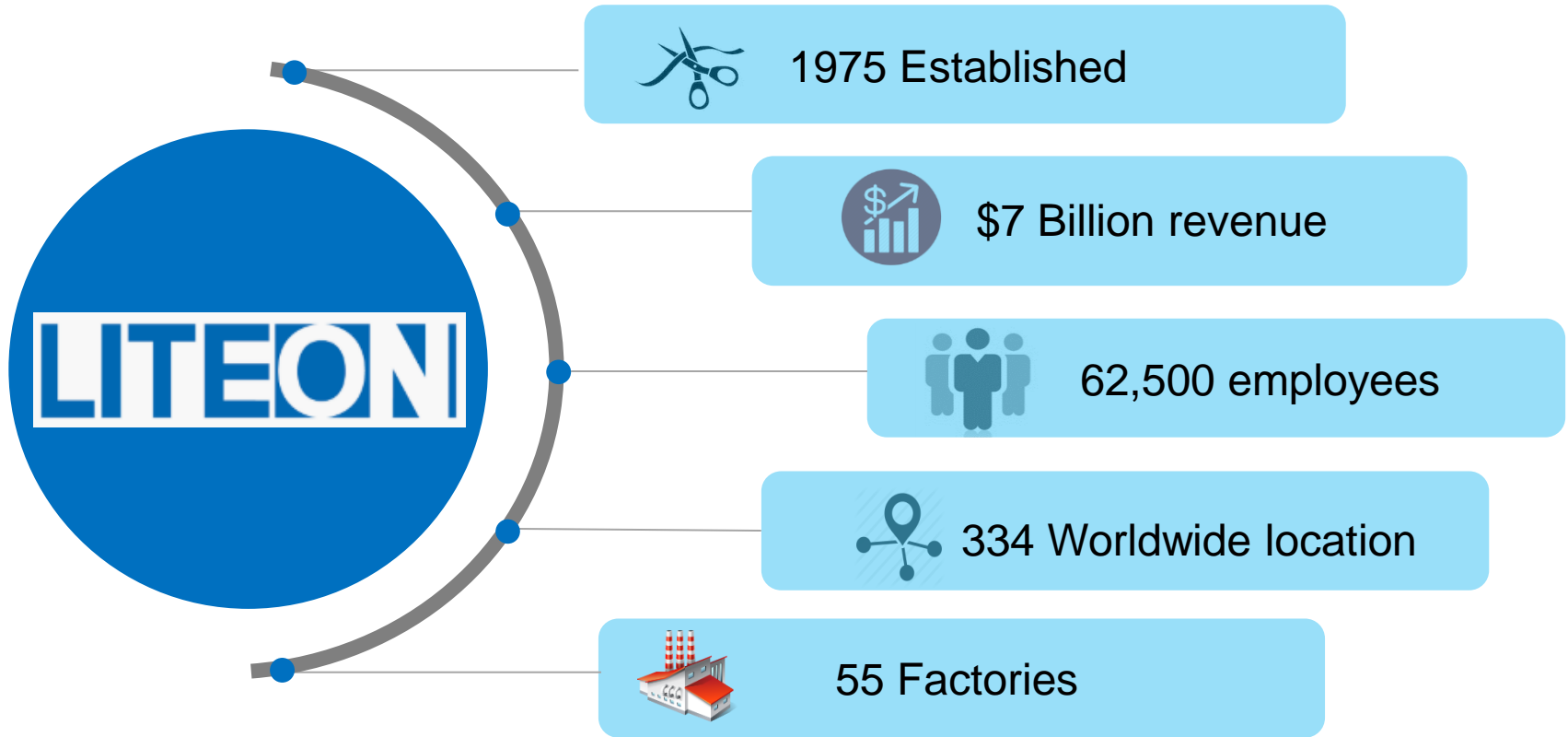
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Agenda

- 1. LiteOn/Ceres Holographics Introduction and Overview**
2. HUD Technology Overview
3. Transparent Display Technology
4. Virtual Image Technology

LITE-ON GROUP



Product Coverage by LITE-ON

Automotive Electronic Applications



Power Supplies



IoT Communication



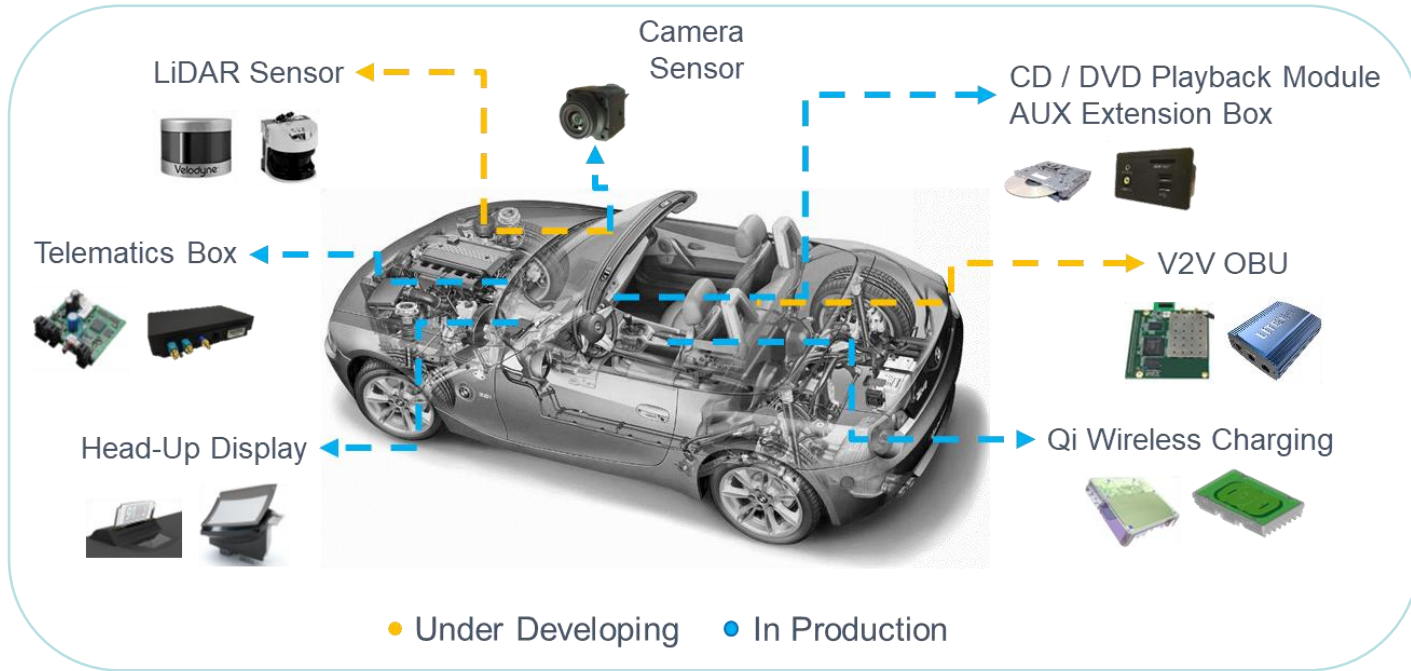
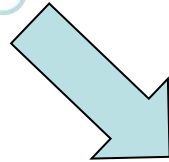
Information Technology



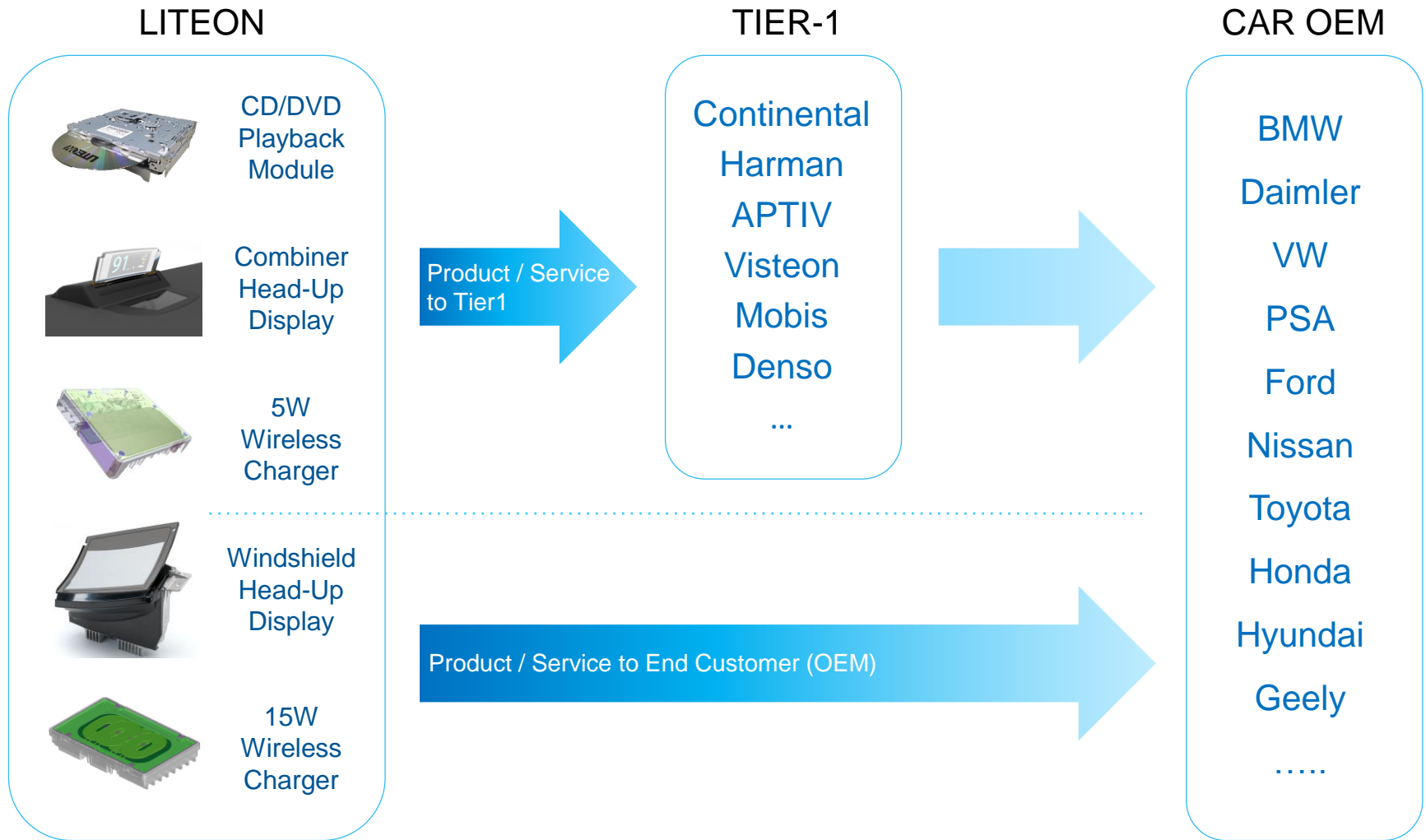
Consumer Electronics



LED Lighting



Automotive Products & Business Role



History, Evolution & Key Dates



1989 PhD in Holographic Optical Elements in Dichromated Gelatin, HW Univ

- All-optical computing systems R&D (SDI/Boeing) (HWU)

1991 NEC Research Institute (Princeton, NJ)

- Holographic data storage in DX-centre semiconductor materials

1999 Co-founder & Chief Scientist of DataPlay Inc., Boulder, CO

- Responsible for key optical IP; first surface recording, micro-optical head

2002 InPhase Technologies Inc. Boulder, CO

- Holographic Data Storage in advanced Photopolymer material
- Led optical drive development optical, servo, mechanical teams

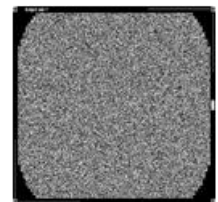
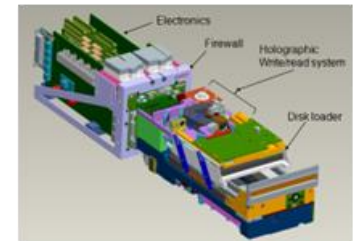
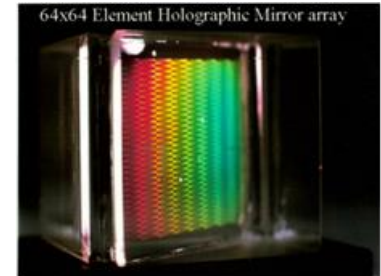
2006 Bayer MaterialScience place a strategic investment inPhase

- For Licence to Photopolymer IP for all non data storage applications

2009 Ceres Imaging Ltd. incorporated, Scotland

2009 – Present: Grant & equity totalling >£2M

- Built 1st and best Digital Printer for origination & mastering
- Proven replication process – primed for machine build and growth phase
- Secured many automotive customers for automotive display prototypes



Ceres Holographics

Volume Holograms in Photopolymer

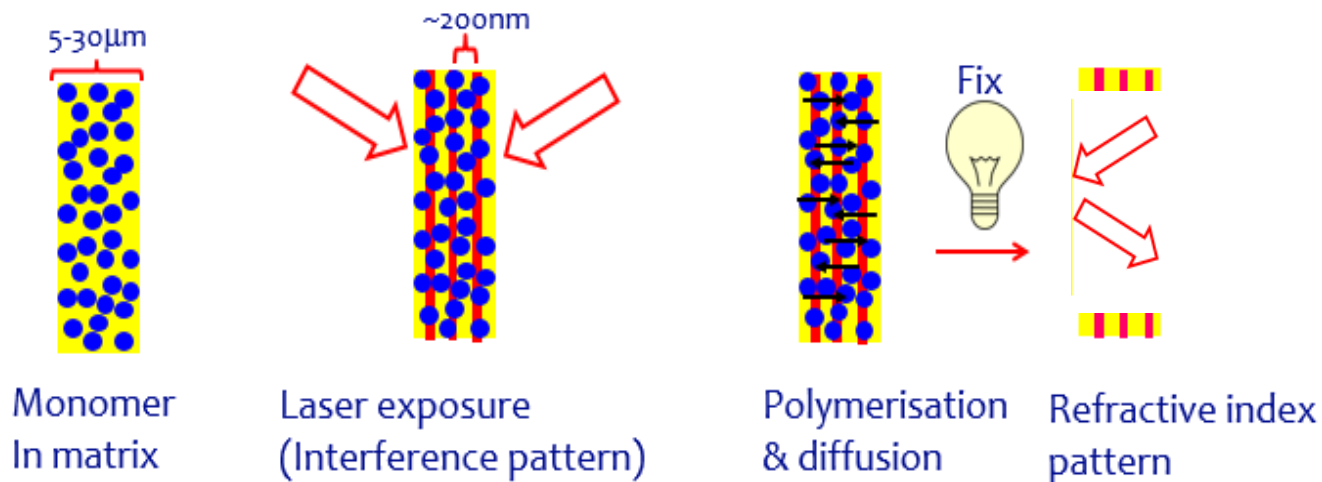


Bayfol® HX photopolymer film – developed by Covestro™



- Significant investment in film development & production since 2006
 - Ceres helped developed & optimise for image and light-guiding applications
 - Ceres have used and characterised over 35 variants since 2009
 - Ceres holographic printer is optimised around these films

Hologram Formation:



Dry, cold process, no by-products



LITEON

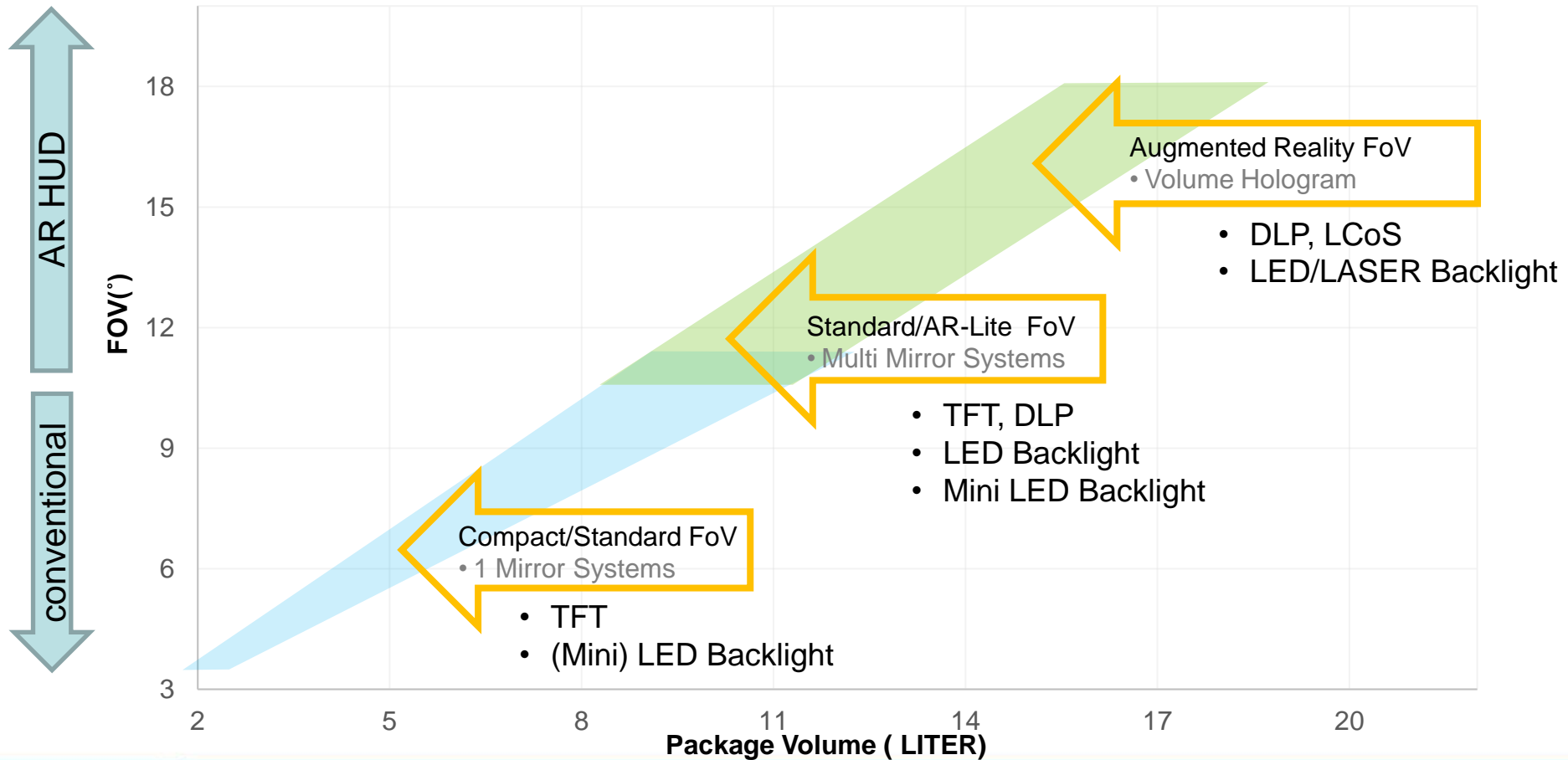
Since 1975

Agenda

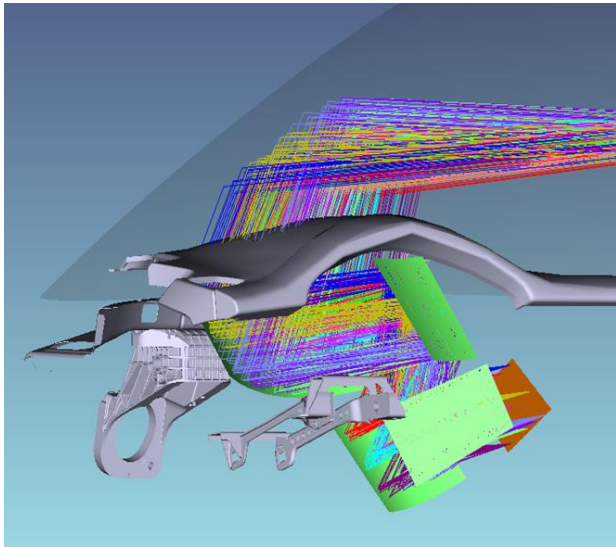
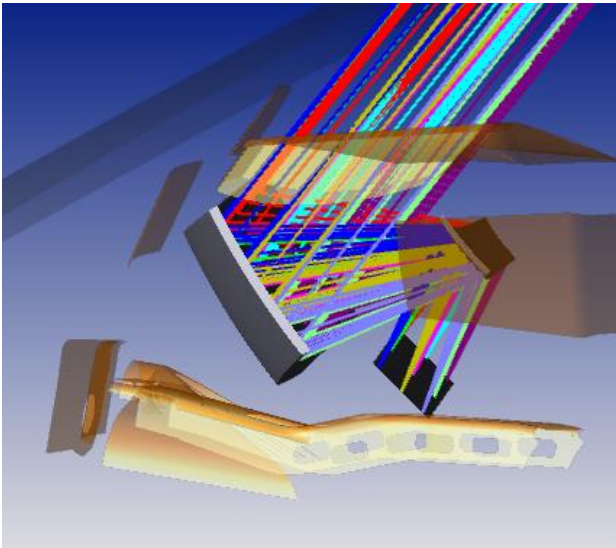
1. LiteOn/Ceres Holographics Introduction
- 2. HUD Technology Overview**
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General HUD Roadmap

- HUD FOV requirements are increasing by HUD applications extending towards AR functionality
- Large FOV's are requiring larger HUD packages and more space/volume in cockpit systems
- Package reduction by using most recent optical technologies

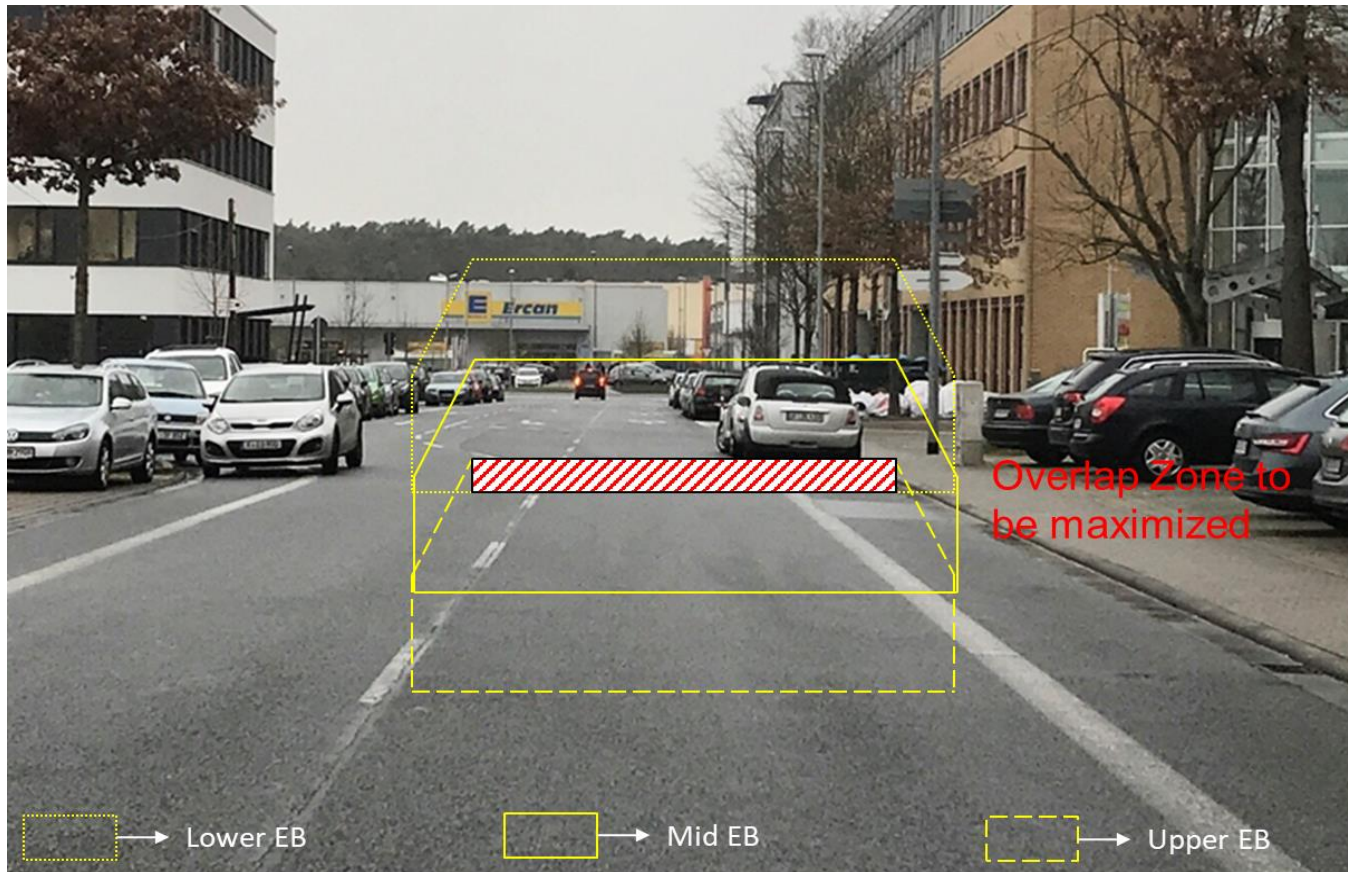


Basic HUD Systems




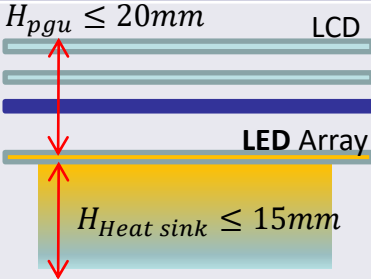
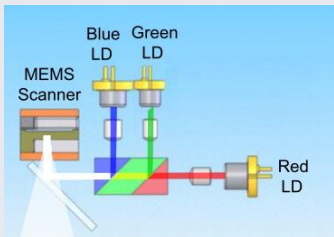
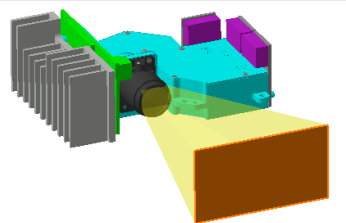
	Standard	Advanced/AR
Optical System	<ul style="list-style-type: none"> • 1 freeform mirror +1 flat mirror 	<ul style="list-style-type: none"> • 2 freeform mirrors • 3 freeform mirrors
Static Eyebox	<ul style="list-style-type: none"> • 130mm x 50mm 	<ul style="list-style-type: none"> • 140mm x 70mm
Image Distance	<ul style="list-style-type: none"> • 2m...3m 	<ul style="list-style-type: none"> • 2m...15m
Field of View	<ul style="list-style-type: none"> • 5°(6°) x 2°(3°) 	<ul style="list-style-type: none"> • 12°(15°) x 4°(5°)
Imager Type	<ul style="list-style-type: none"> • TFT (1"/1.8"/3.14") 	<ul style="list-style-type: none"> • TFT (>3.14") • DLP • R-G-B Laser
Image Resolution	<ul style="list-style-type: none"> • >70pix/° 	<ul style="list-style-type: none"> • >80pix/°
max. Brightness	<ul style="list-style-type: none"> • 12k cd/m² 	<ul style="list-style-type: none"> • 12k cd/m²
Dimming Ratio	<ul style="list-style-type: none"> • 5000:1 	<ul style="list-style-type: none"> • 5000:1
FoFo Contrast	<ul style="list-style-type: none"> • >1000:1 	<ul style="list-style-type: none"> • >1500:1
Box Volume	<ul style="list-style-type: none"> • <12L 	<ul style="list-style-type: none"> • ...15L...40L

AR Head Up Displays



- Real AR content is only useful in the overlapping zone
- this zone is to be maximized by maximizing static vertical eyebox = box size increase!
- LookDownAngle shift can be avoided by moving the whole system = box size increase!

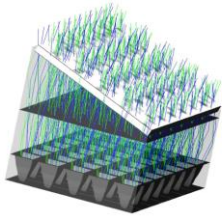
PGU-Type Selection

	LCD/Backlight	LCD/Mini LED Backlight	Laser Scanning MEMS	Projection (DLP/LCoS)
Pixels	<ul style="list-style-type: none"> 480 x 240... 1280 x 640 	<ul style="list-style-type: none"> 480 x 240... 1280 x 640 	<ul style="list-style-type: none"> typical 1280 *720 	<ul style="list-style-type: none"> 1152 x 576 (DLP) Full HD (LCoS)
Panel size	<ul style="list-style-type: none"> 1.8"/2.6"/3.1" 	<ul style="list-style-type: none"> 1.8"/2.6"/3.1" 	<ul style="list-style-type: none"> up to 100mm 	<ul style="list-style-type: none"> up to 120mm
Image quality	<ul style="list-style-type: none"> Very Good 	<ul style="list-style-type: none"> Very Good 	<ul style="list-style-type: none"> Poor...Medium 	<ul style="list-style-type: none"> Good
Advantages	<ul style="list-style-type: none"> Sharpest images most compact imager thickness < 45mm 	<ul style="list-style-type: none"> Sharpest images most compact imager thickness < 45mm 	<ul style="list-style-type: none"> Low power High color gamut 	<ul style="list-style-type: none"> High color gamut Un-polarized light (DLP) Thermal stability Variable image size
Disadvantage	<ul style="list-style-type: none"> Potential sunlight burning, e.g. Bonanza effect Efficiency 	<ul style="list-style-type: none"> Potential sunlight burning, e.g. Bonanza effect Efficiency 	<ul style="list-style-type: none"> Sharpness Contrast loss through incoming light Speckle 	<ul style="list-style-type: none"> Sharpness Contrast loss through incoming light Size Optical effort
Image				
Potential suppliers	<ul style="list-style-type: none"> LCD : KYOCERA, JDI... LED : OSRAM, Nichia or LITEON 	<ul style="list-style-type: none"> LCD : KYOCERA, JDI... LED : Lextar or LITEON 	<ul style="list-style-type: none"> MEMS : UltiMEMS Laser : OSRAM/Nichia 	<ul style="list-style-type: none"> DMD : TI LED : OSRAM Laser : OSRAM/Nichia

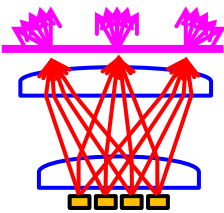
HUD Imager: TFT Technology + LED

TFT Based

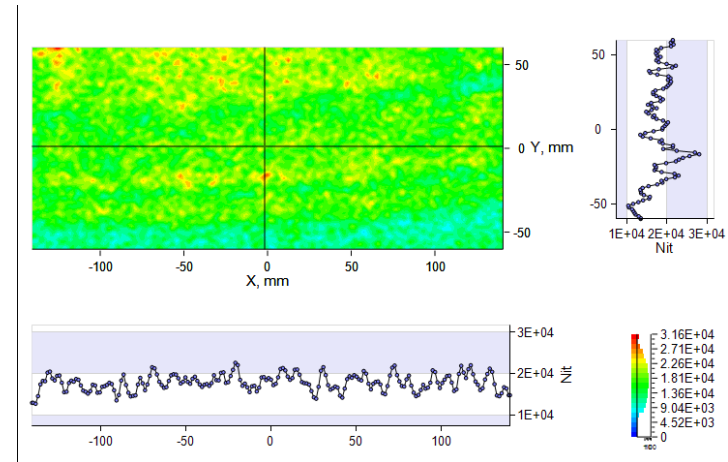
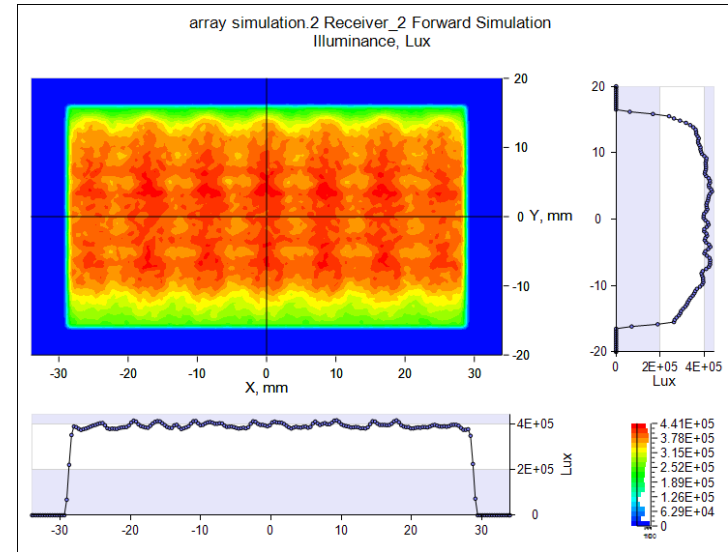
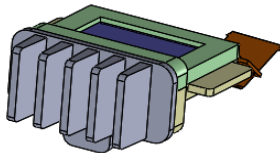
High Uniformity(Matrix Type)



High Efficiency(TIR/Lens Type)

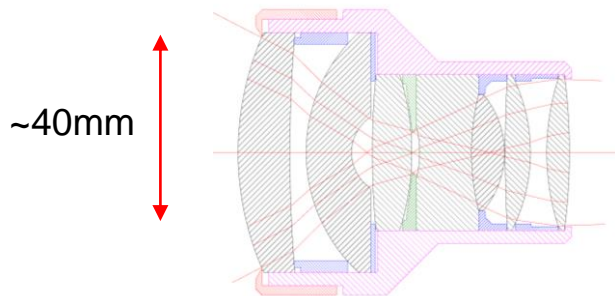
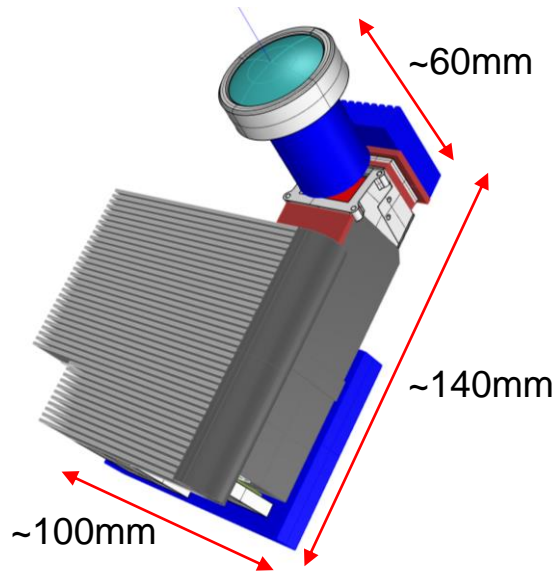


Ultra Thin(Side edge type)



HUD Imager: DLP 5530 + LED

- LiteOn modular DLP projector with LED lighting
- modular, customizable design
- inhouse design, matched to HUD design (pupil matching)

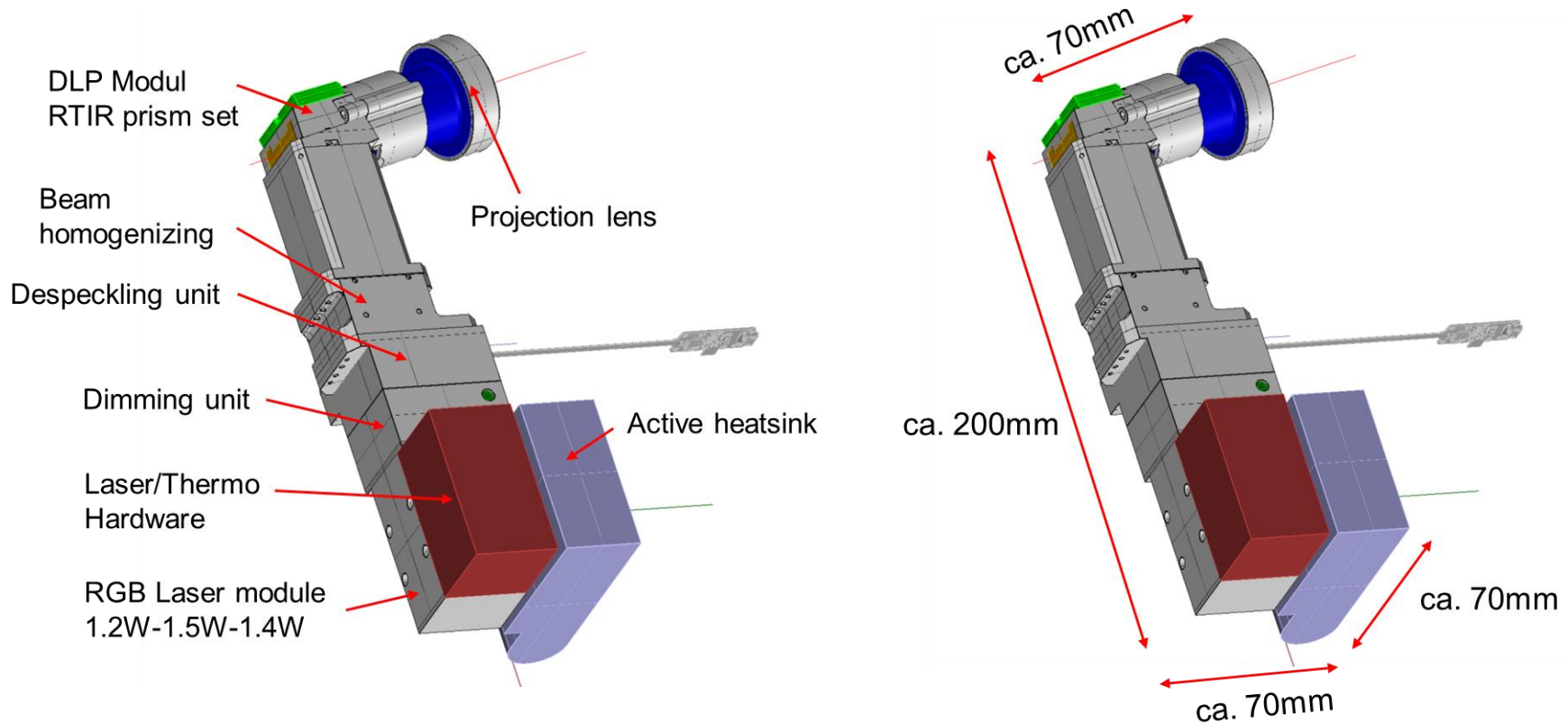


Key Parameters

Design	<ul style="list-style-type: none"> • LiteOn modular design based on DLP 5530 • custom automotive grade lens design
Resolution	1172pix x 576pix
Distortion	< 2%
LED	<ul style="list-style-type: none"> • Osram Q7, Q8, P1
ANSI output lumens	<ul style="list-style-type: none"> • >700lm based on Osram Q7 • >1000lm based on Osram P1
Size	<ul style="list-style-type: none"> • ~140mm x 100mm x 60mm • Volume < 1Liter
Automotive grade	yes
Dimming	<ul style="list-style-type: none"> • 5000:1 dimming
Image Brightness	<ul style="list-style-type: none"> • >12000 cd/m² for 12°x4° FoV • >80% homogeneity
Contrast	<ul style="list-style-type: none"> • >1500:1 • not sensitive to ambient light/sunlight

HUD Imager: DLP 5530 + Laser

- LiteOn modular DLP projector with Laser lighting
- thermally stabilized RGB Laser backlight (<math><0.5\text{nm}</math>)
- despeckled
- dimming ratio $\sim 5000:1$ (wavelength stable)
- inhouse design, matched to HUD design (pupil matching)





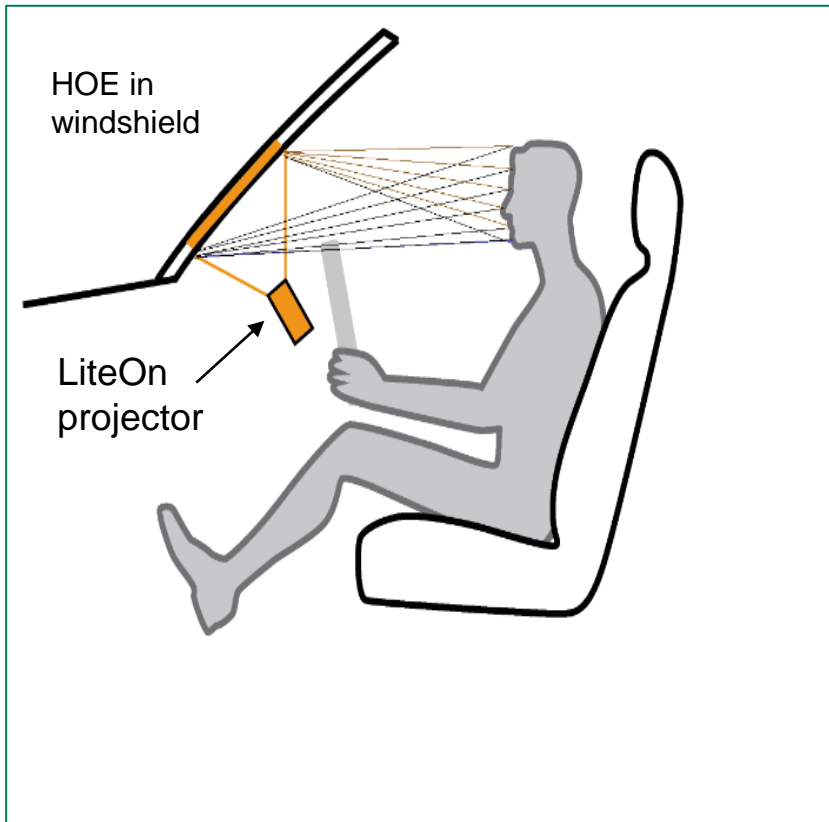
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Transparent Display Technology

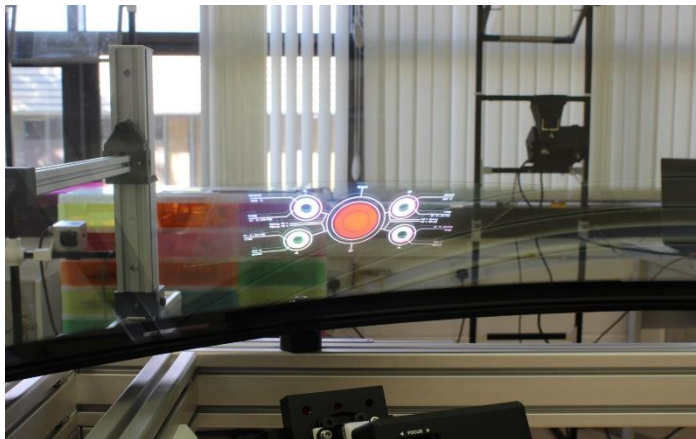
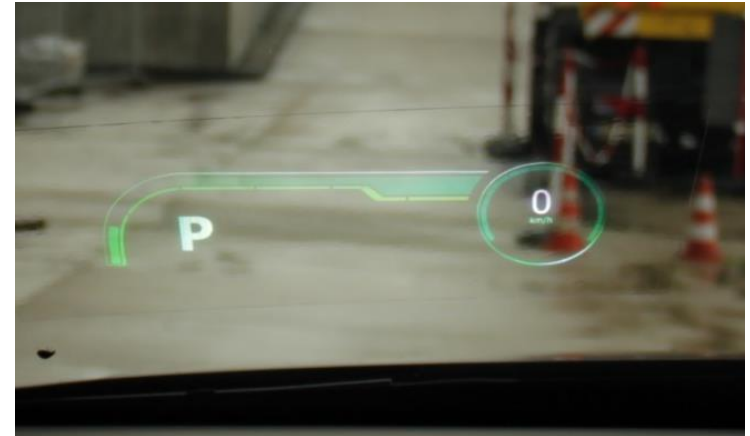
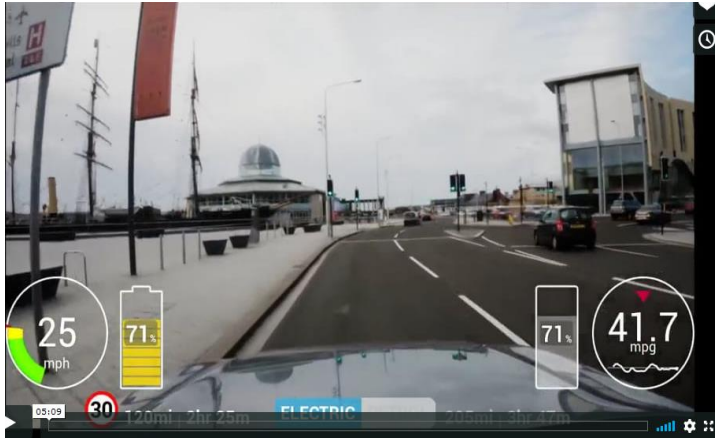


- Target Application: replacement of instrument clusters
- Volume Hologram (HOE) embedded in the windshield:
 - color selective, reflective screen
 - controlled divergence angle to fill the drivers eyebox for reliable and safe visualization
 - real image on windshield
 - 80% transparency in VIS, no legal problems expected
- LED based Projector is working well, LASER light source is not necessary
- Small size: DLP projector size will be < 1 Liter
- Design friendly dashboard integration: dashboard hole is small compared to standard HUD
- Image size limited by projector output power power and HOE limits, but can be as large as 400mm x 200mm

Transparent Display Technology

Transparent Display Technology (©CERES Holographics)

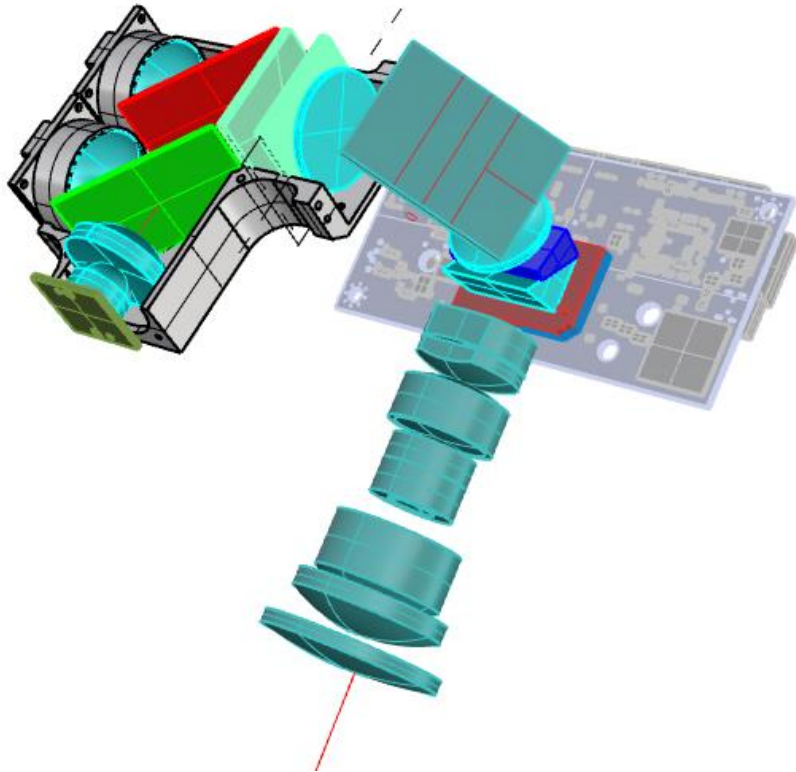
<https://vimeo.com/373887033/150a2a6314>



- Transparent display replacing instrument cluster (©VW,Porsche)
- HOE film is almost invisible
- High brightness (>15knits) and contrast achievable
- Design friendly integration (projector package <1Liter)
- still some color artifacts, but acceptable

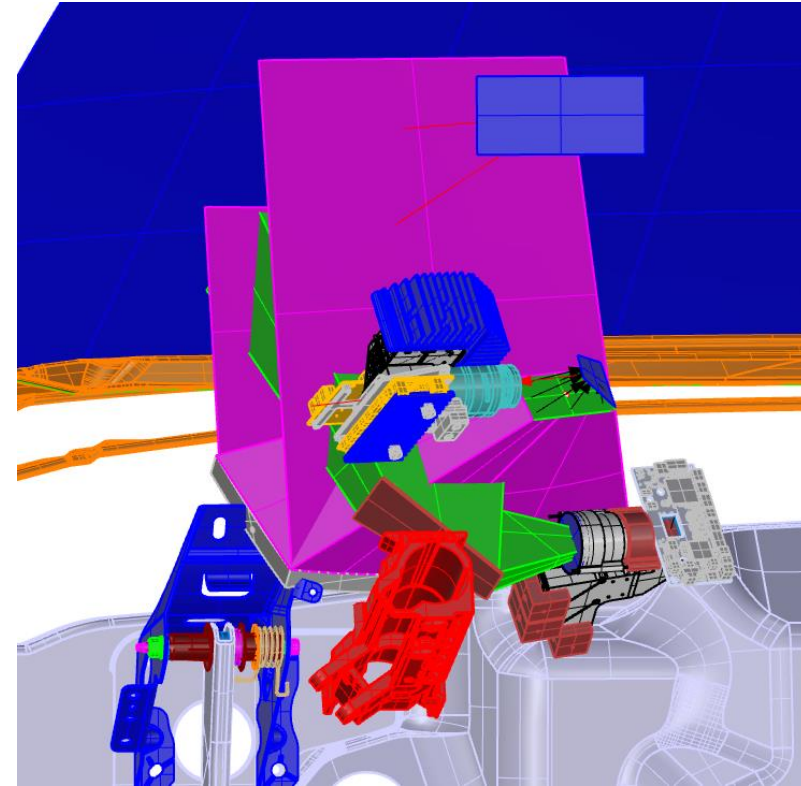
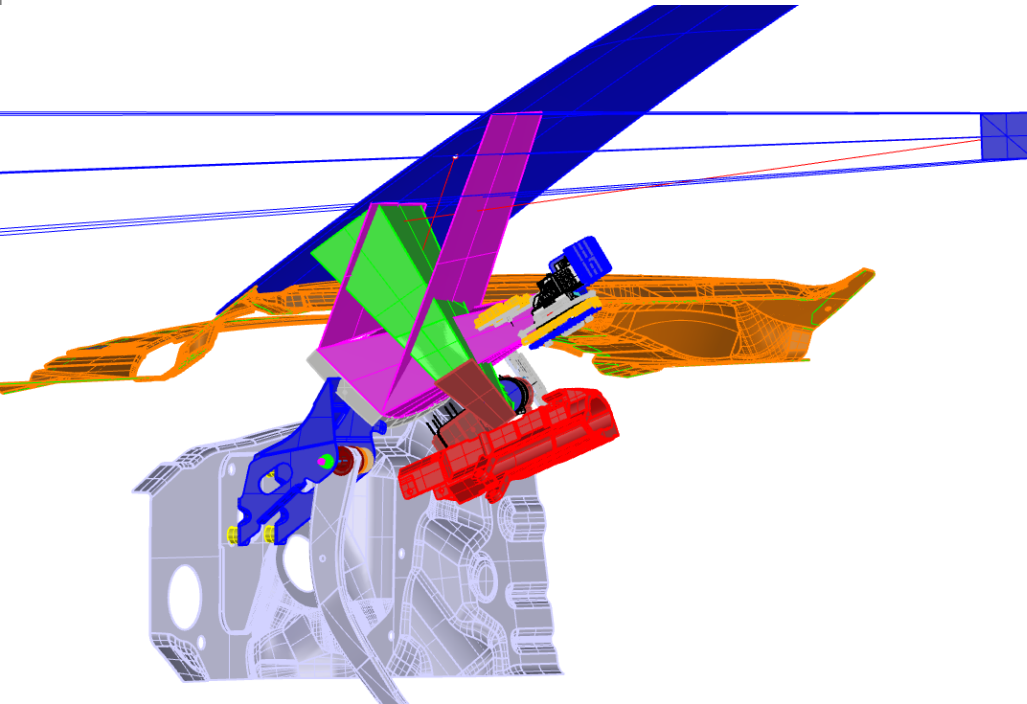
Transparent Display Technology

LiteOn High Power DLP Projector



Parameter	Requirement
DLP Chip Set Version	Texas Instruments DLP 5530 0.55"
Image Size	Up to 400mm x 200mm
Throw distance (lens to screen)	200mm...400mm (customer specific)
Custom lens design	<ul style="list-style-type: none"> All glas (aspherical+spherical) No cemented elements High VIS transmission mandatory F-stop ~ T-Stop
Field curvature	<ul style="list-style-type: none"> customized to fit windshield
TV-Distortion	< 4%
Polychromatic MTF (center)	<ul style="list-style-type: none"> Design : 55% @ 3 Lp/mm Built : 45% @ 3 Lp/mm
Lateral color	< 1.5 Pixel
System f-number	< f/2.4, elliptical aperture allowed < 20% vignetting
Vignetting	< 20%
LED set	Osram Q7 (Red/TrueGreen/Blue)
Output	>300lm ANSI with True Green LED
Contrast	> 1500:1 FoFo > 800: Checkerboard (off the HOE)
Temperatur range	-40°C...85°C (105°C) operating

Transparent Display Technology



- Combined AR-HUD (purple) and Transparent Display (green) for major US Customer
- No more instrument cluster in car



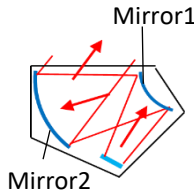
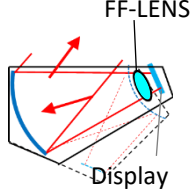
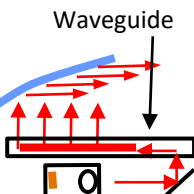
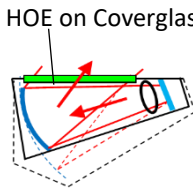
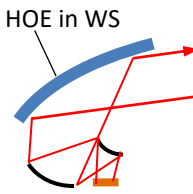
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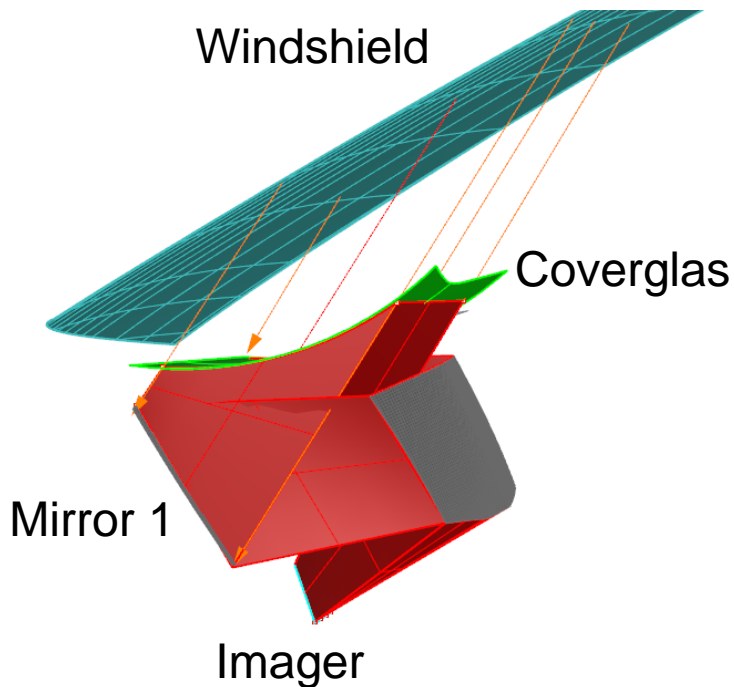
HUD Package Size-Issue

	Current HUD Technology Maxed out since years		Holographic Optical Elements		
	Standard	Catadioptric optical system	Wave Guide optical system	Volume Hologram on coverglas	Volume Hologram embedded in windshield
Technology					
Technology	<ul style="list-style-type: none"> • Freeform Mirror Optic: 1..2 freeform mirrors for aberration correction • All kind of imagers and light sources • Managed parasitic reflections 	<ul style="list-style-type: none"> • Catadioptric system: 1 freeform mirror + 1 freeform lens • Reduced optical path length by refractive elements • All kind of imagers and light sources • Sensitive to parasitic reflections from ambient light 	<ul style="list-style-type: none"> • HUD replaced by WaveGuide Optics • Reduced package size of optical system by holographic waveguide inside the usual HUD exit-aperture • Laser imager mandatory • Sensitive to parasitic reflections from ambient light • Contrast lower than usual 	<ul style="list-style-type: none"> • Replace Cover glass with hologram (HOE) • Package reduction by volume hologram on coverglass • Laser imager mandatory • Distributed optical power between mirror and HOE • Can be installed in usual place..can be backed up by standard technology • Managed parasitic reflections 	<ul style="list-style-type: none"> • Hologram (HOE embedded in WS) • Hologram combiner works like a lens which increases the optical power of the WS in a smart way • Laser imager mandatory • Reduced size of main mirror and HUD aperture • No moving parts, but still big eyeboxes • Parasitic reflections not yet 100% understood and managed

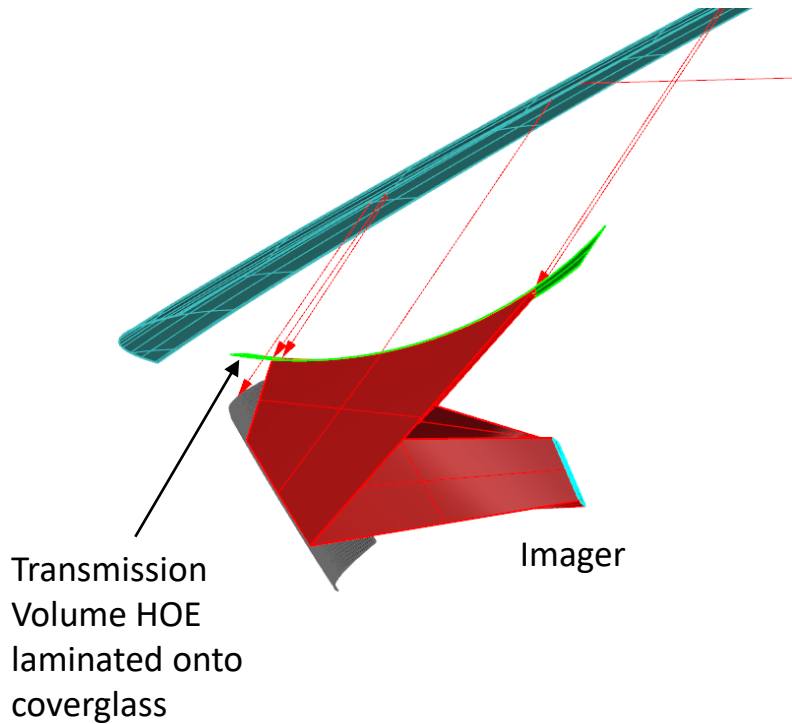
Standard Technology

Package Size, Critical Parameters

- Windshield-Geometry, Eyebox-Size and Image Geometrie defining size of:
 - Dashboard CutOut
 - Coverglass
 - Mirror 1
- 1 up to 2(3) freeform mirrors (depending on Ws geometry and magnification) for compensation of optical aberrations
- FreeForm mirror system requires a lot of package space, interference issues with:
 - Steering wheel column
 - Cross-car-beam
 - Airducts, Firewall...
 -
- Current standard tech. image size limit is to $\sim 10^\circ \times 4^\circ$ FoV



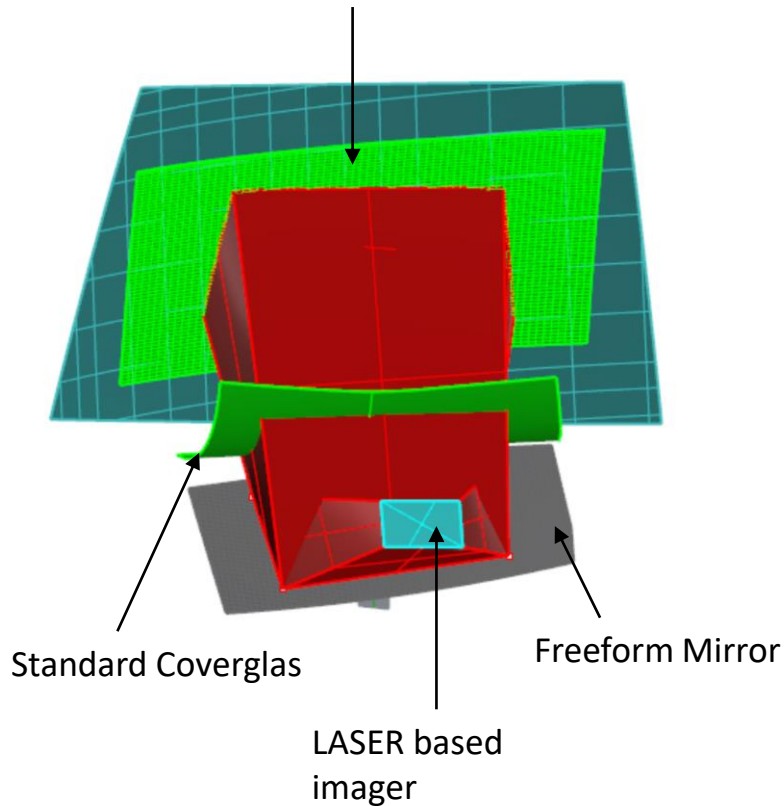
Volume Hologramm on HUD Coverglass



	Assessment
Function	<ul style="list-style-type: none"> • A volume hologram (HOE) is laminated onto the coverglas • The smartly designed HOE is reducing WS aberrations before entering the optical system beneath and is increasing optical power of the system
Benefits	<ul style="list-style-type: none"> • Size of main mirror can be significantly reduced • HUD can be installed in the usual position...so a BackUp with standard tech is possible • Overall package could be reduced by ~20%...30%, especiall in z direction
Draw Back	<ul style="list-style-type: none"> • Parasitic Reflections from HOE not fully understood and managed yet • Narrow band, thermal stable LASER light source is mandatory! • HUD can not installed in usual pos AOI should be below 50°...no standard tech BackUp
Status	<ul style="list-style-type: none"> • Requires further technology development: <ul style="list-style-type: none"> • Simulation • Mastering • Massproduction • Laser source • Film embedding • SOP target ~2026 not realistic

Volume Hologram embedded in WS

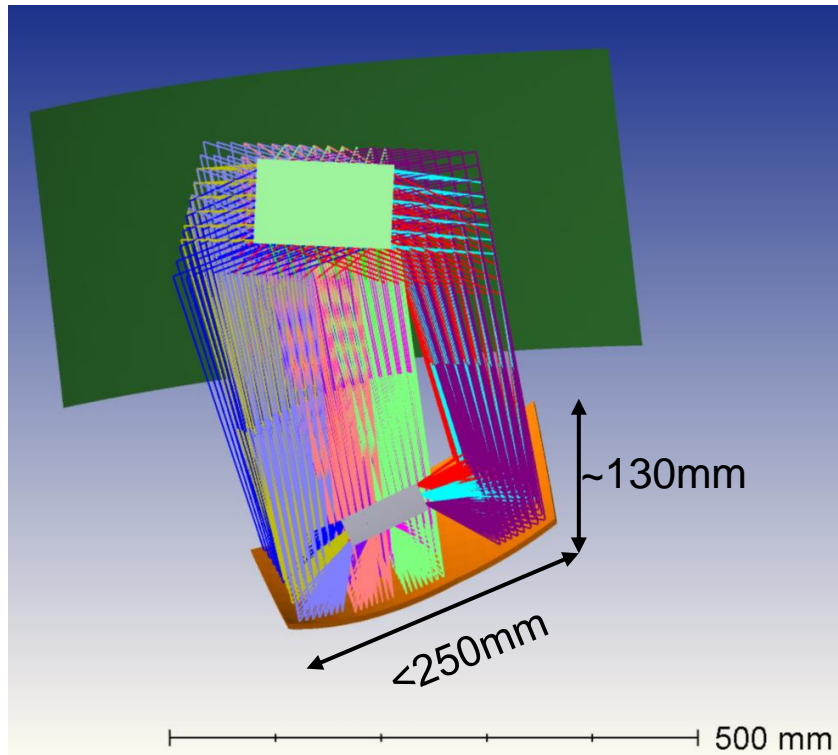
Volume HOE embedded in windshield



	Assessment
Function	<ul style="list-style-type: none"> • Ray bundle size reduction through higher magnification with less distortion by embedding a transparent (>80%) volume hologram in a WS • Package can be significantly reduced: smaller main mirror, dashboard cut-out, coverglass • Only 1 freeform mirror is needed, HOE reduces aberrations significantly
Benefits	<ul style="list-style-type: none"> • Overall package reduction ~ 50%...70% • Highest potential of package reduction, e.g. 15° x 5° in a 8°x3° package
Draw Back	<ul style="list-style-type: none"> • Parasitic Reflections from HOE not fully understood and managed yet • Narrow band, thermal stable LASER light source is mandatory! • HUD can not installed in usual pos AOI should be below 50°...no standard tech BackUp
Status	<ul style="list-style-type: none"> • Requires further technology development: <ul style="list-style-type: none"> • Simulation • Mastering • Massproduction • Laser source • Film embedding • SOP target ~2026 not realistic

Volume Hologram embedded in WS

Package Reduction by advanced HOE (transparent Volume Hologram)



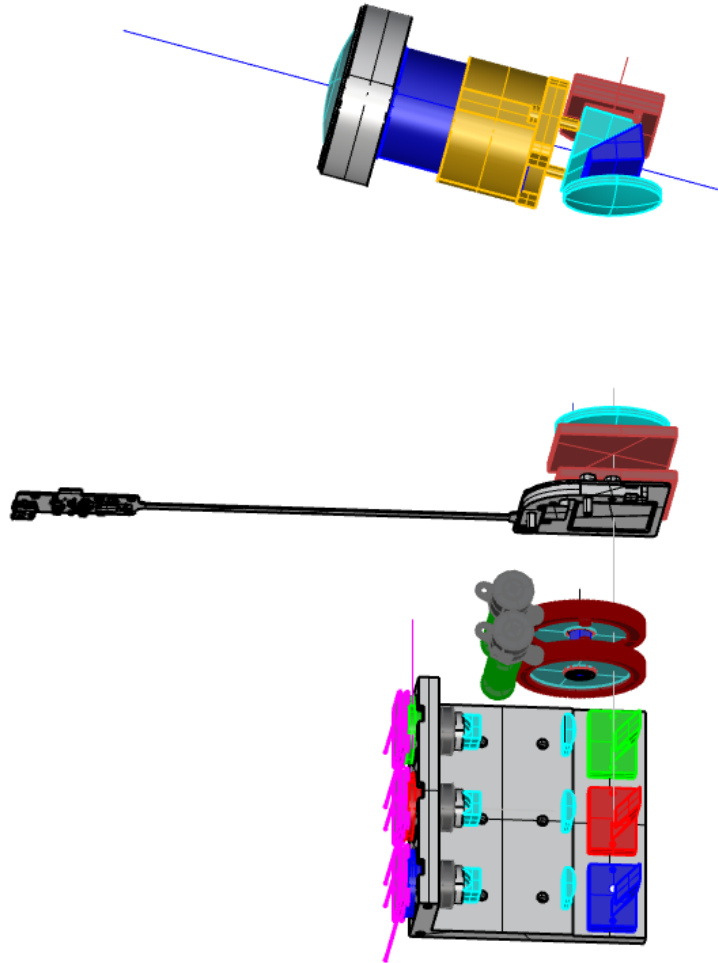
BMW prototyp

Assessment of a realized Proto System

- FoV 15°x 5°
- RGB, 10k nits
- VID 10000mm
- Eyebox size 130mm x 100mm
- High optical performance
- Package ~ 10Liter
- Advanced HOE design on real, curved windshield
- DLP Imager with thermal stabilized and de-speckled R-G-B LASER implemented
- currently, HOE glare or similar effects seems not to be avoidable, but can be reduced to a point which may be acceptable
- HUD/HOE design strategy to be developed

Real Image / InPlane Technology

LiteOn Laser Projector Prototype



- 1.4W @460nm
- 1W @539nm
- 1.2W @639
- Target $< \pm 1$ nm thermal stabilisation (with TEC)
- dimming: mechanical
- despeckleed (vibrating diffusor)
- 0.55" DLP
- Lens: custom design

Volume Hologramm embedded in WS

Challenges and Risks...Our need for “PhoSMA”

- System design and limitations are not fully understood
- HOE: glare effects needs to be fully understood and a **simulation tool chain** needs to be developed and verified
- HOE mastering and production: digital HOE recording on curved surfaces is not fully developed and understood yet, serial production of HOE needs to be setup and evaluated
- Imager: **Narrow bandwidth, thermally stabilized, diammable LASER sources** needs to be developed for automotive environment, specs and cost
- HOE optical tolerancing not available
- Thermal effects on embedded HOE not fully evaluated
- HOE embedding/laminating: HOE embedding is not a qualified process yet, but very significant progress was achieved during the past 12 month
- **Strong collaboration between all project partners is absolutly mandatory**

Thank You!

Dr.-Ing. Ralf Mayer

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