Optical Microstructures in Exterior Lighting:

Big Opportunities with Tiny Dimensions

Todd Morgan – Senior VP Product Development
Tomas Gloss – Technical Fellow Signal Lighting

Agenda

What are microstructures

Why are they important / potential applications

Methods of implementation (foils vs. in-mold)

Challenges of implementation

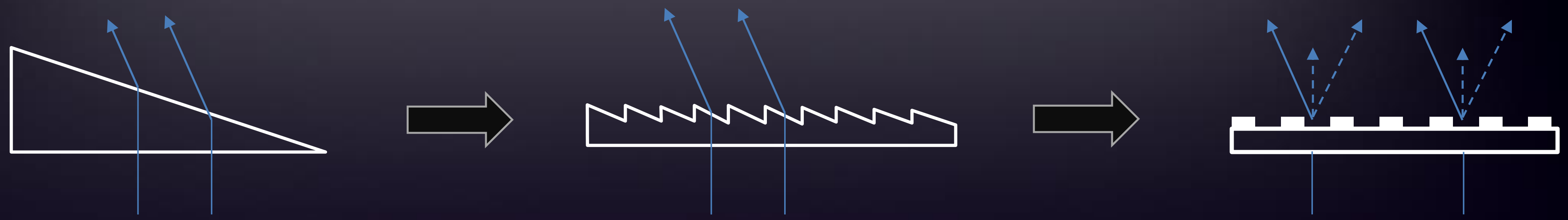
Homogeneity / efficiency comparison

Summary

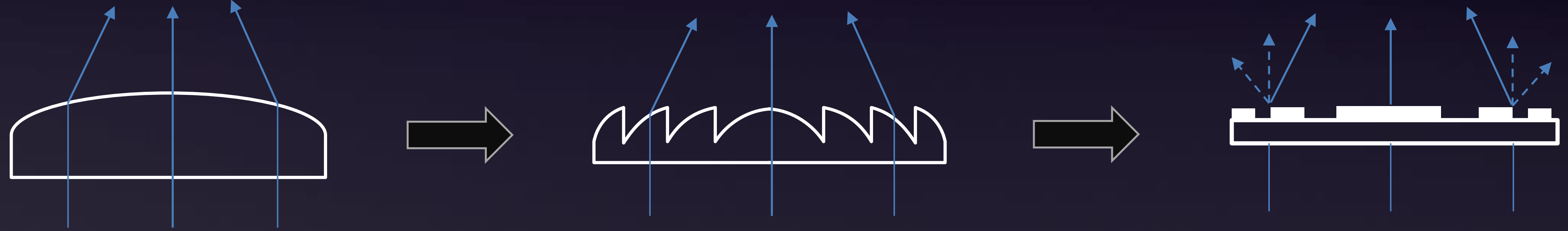
MICROSTRUCTURES IN GENERAL

WHAT ARE MICROSTRUCTURES?

REFRACTIVE PRISM — MICRO PRISM ARRAY — BINARY DIFFRACTIVE GRATING



REFRACTIVE LENS — MICRO FRESNEL LENS — BINARY DIFFRACTIVE LENS



THE DIMENSIONS OF OPTICAL ELEMENTS GOES FROM ~1-2MM TO ~1-300 MICRO METERS OR IN CASE OF DIFFRACTIVE OPTICS IT IS IN THE RANGE OF NANO METERS.

Types of structures for our applications

Various types of structures are investigated in Varroc to be used for lighting applications

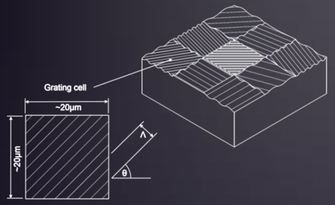
Gratings

- Sinusoidal 
- Binary 
- Multi-Level 
- Blazed 

Key features

Sinusoidal	Lowest probability of degradation, lowest efficiency
Binary	possibility to reduce stray light >> higher efficiency
Multi-level	Asymmetric light distribution, more complex manufacturing
Blazed	Highest efficiency and possibility of asymmetric light distribution

Additional types of structures for our applications

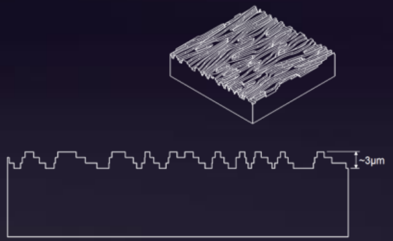


Cell arrays / Lens arrays

- Gratings arranged in the cell array to achieve various functionality
- Beam shaping, homogeneity improvements, special visual effects

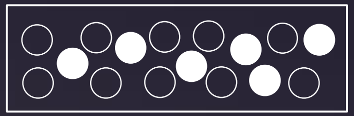
Micro prisms

- Intermediate step between standard optics and diffractive structures (Micro machining is used in VLS)



Surface DOEs (Diffractive Optical Elements)

- Various diffractive elements with various shapes
- To achieve special functionality and control the light beam

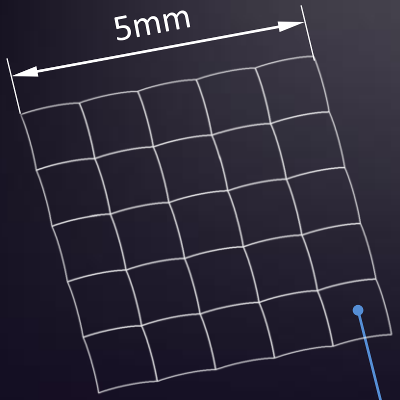


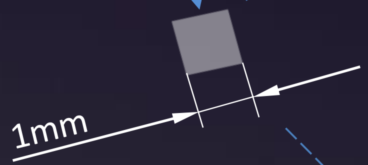
Volume structures

- Optical structure recorded in photo polymer material (usually foil)
- Used in VLS mainly for holography

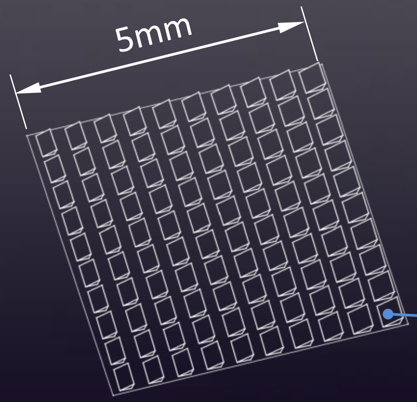
What is the size of the structures are we talking about?

Standard optical pillows 1x1 mm



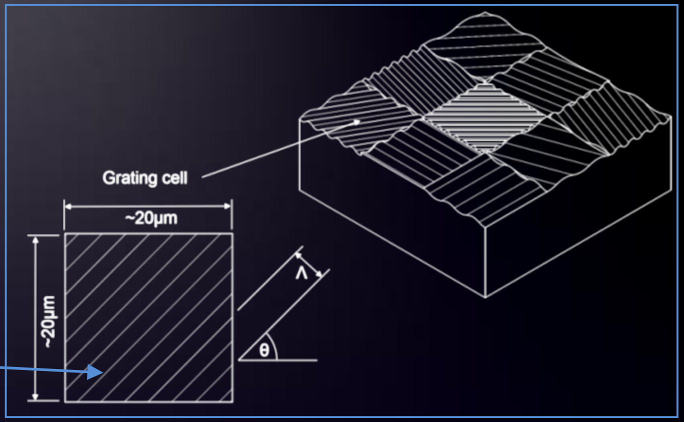


Micro prisms 200 x 400 µm

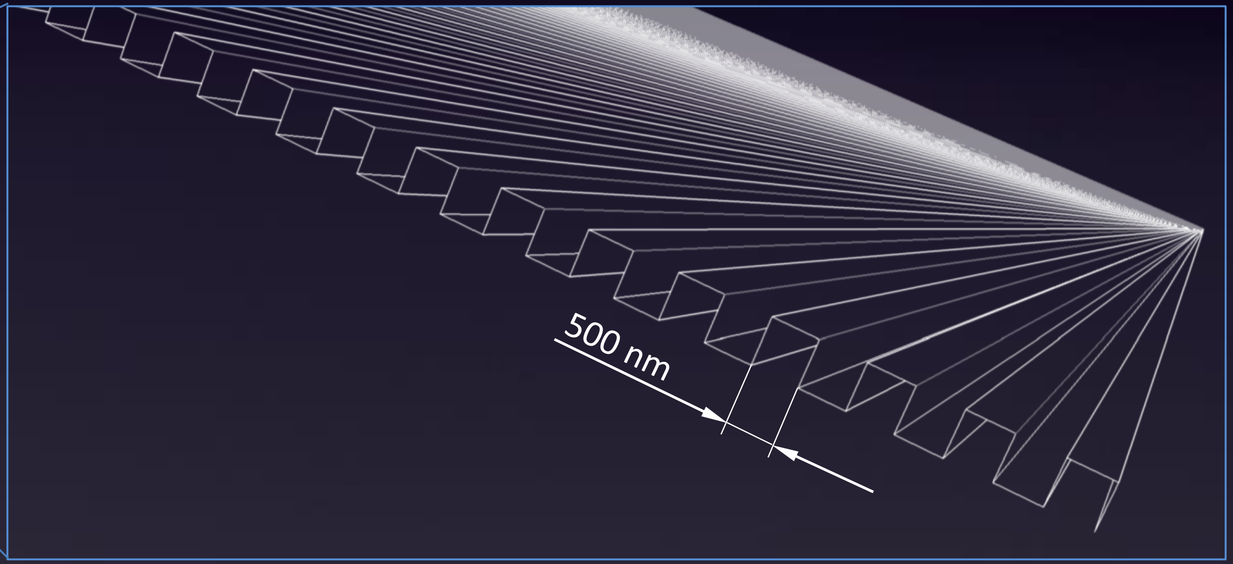


100 x smaller cell

Grating cell array (20 x 20 µm)



Binary grating with pitch of 500 nm (2000 elements on 1mm of length)



Potential of microstructures in lighting applications

Better efficiency of optical systems with the same or better level of homogeneity compared to standard optics

Very fine optics for standard optical concepts (light pipes, light blades, inner lenses, reflectors) >> Innovation in styling (Invisible optics)

Package reduction possibility

Completely new lighting concepts (e.g. Surface-LED)

Holography applications for lighting communication

Huge potential together with Laser LEDs in future to dramatically reduce power consumption

Road projection applications (Advanced Safety Features)

MICROSTRUCTURES ON FOILS OR DIRECTLY IN THE MOULDING TOOL

TWO OPTIONS OF APPLICATION ARE NOW INVESTIGATED IN VLS

MICROSTRUCTURES ON FOILS (MASTER IS HEATED AND PRESSED AGAINST PLASTIC FOIL WITH RESIN)

PROS

- LOWER COST FOR LARGE STYLING AREAS
- VOLUME STRUCTURES (BETTER FOR HOLOGRAPHY)
- R2R MANUFACTURING (POSSIBLE ONE TOOLING FOR SEVERAL PROJECTS)
- ALREADY IN PRODUCTION (PROVED TECHNOLOGY)

CONS

- ADDITIONAL PART IN THE LAMP (ADDITIONAL OPERATION IN MANUFACTURING)
- ONLY 2.5D SHAPES WITHOUT THERMOFORMING PROCESS
- COMPLICATED THERMOFORMING PROCESS FOR 3D (WITH RESPECT TO OPTICS)

MICROSTRUCTURES IN THE TOOL (MASTER IS IMPLEMENTED IN THE TOOL AS INSERT >> “STANDARD” INJECTION MOULDING PROCESS IS USED)

PROS

- MICRO OPTICS ON COMPLETELY FREE 3D SHAPES
- OPTICS CAN BE APPLIED TO THE EXISTING COMPONENTS IN THE LAMP

CONS

- MORE TIME CONSUMING CALCULATIONS + TOOLING DATA EXCHANGE
- TOOL MAINTENANCE AND MOLDING FEASIBILITY LIMITATIONS

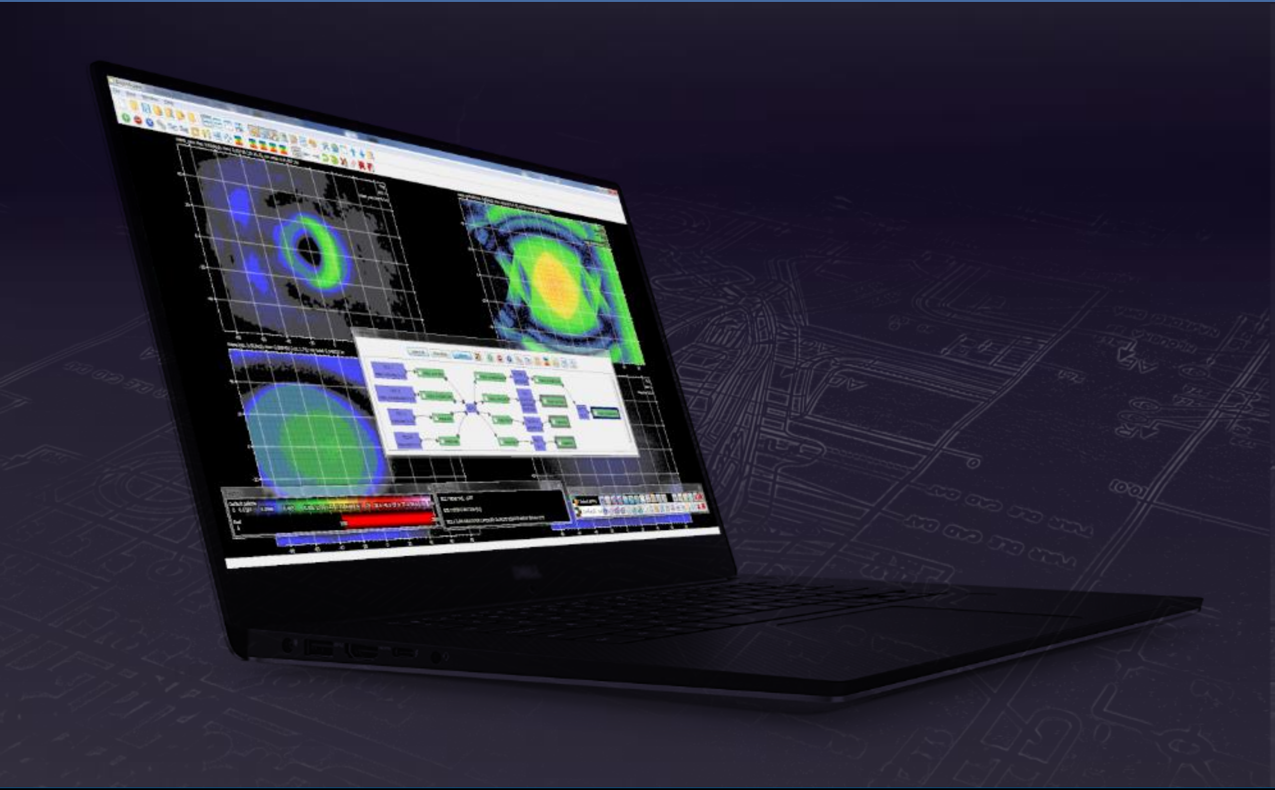
CHALLENGES FOR DESIGN AND MANUFACTURING | SOFTWARE AND TOOLING

It is not possible to calculate micro optics in standard way (CAD creation > Raytracing > Analysis of result > Tuning loop)

Raytracing cannot be applied for diffractive optics (diffraction needs to be taken into account)

Almost all CAD data of head lamps and rear lamps are created like NURBS surfaces in CAD software but micro optics cannot be done in this way

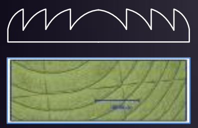
Therefore in VLS we are combining commercial software tools together with internally developed ones to have full capability of simulation and data export for manufacturing



Challenges for Design and Manufacturing | Theory and Reality

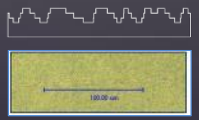
There are several types of microstructures used in different industries but not all of them are good for injection moulding process.

Structure Type 1 – Micro Fresnel lenses



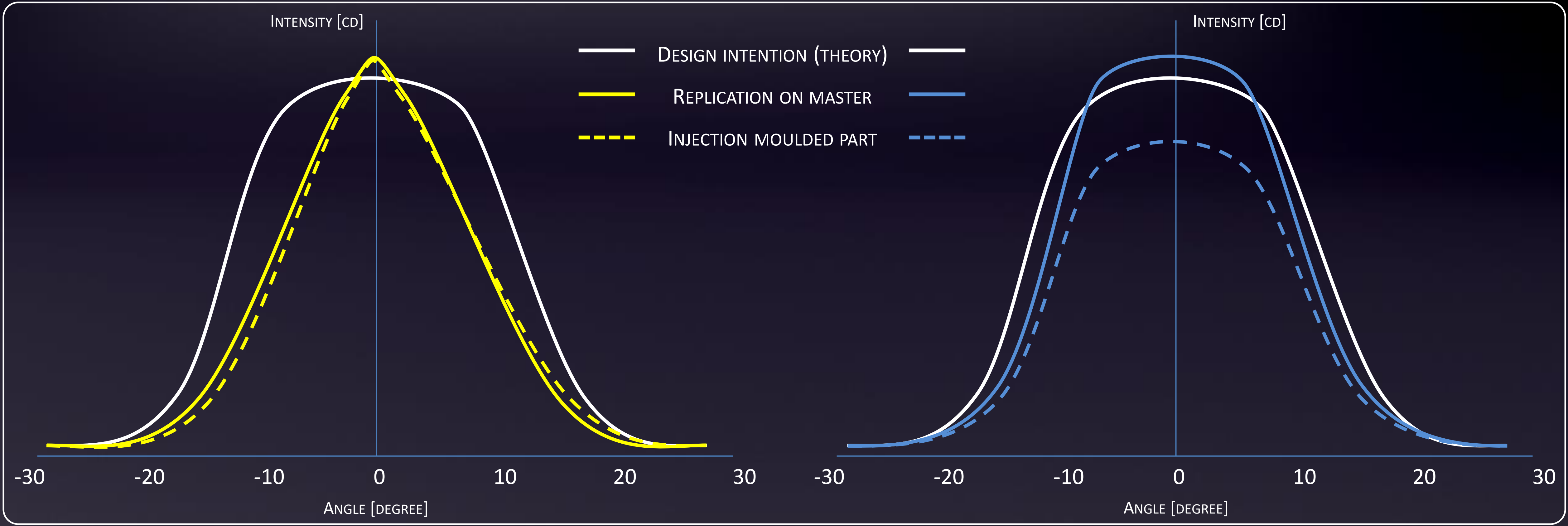
- Almost no difference between master and injection moulded part
- Good structure for injection moulding process
- Not very good correlation between theoretical calculations and physical parts

Structure Type 2 – Multilevel DOE



- Better matching between design intention and master
- Much bigger difference between master and injection moulded part
- Good structure for mastering, worse for injection moulding process

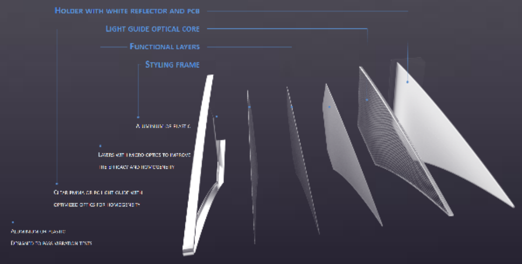
Intensity angular distribution graphs



Foil application examples

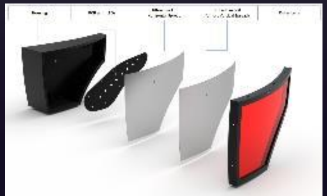
Surface-LED

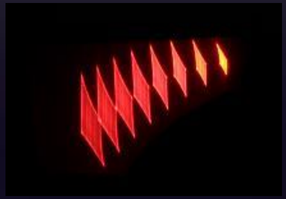
New innovative concept for flat package of lighting modules is using several layers with microstructures



3D Holographic like effect

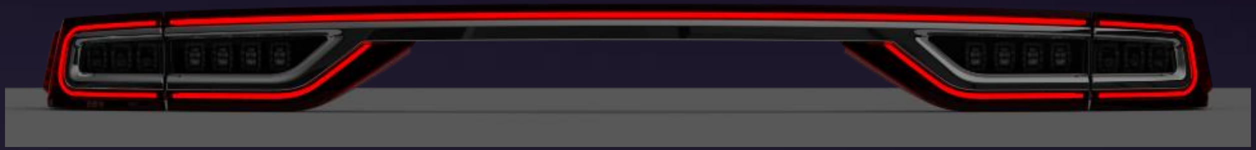
Foils with microstructures are arranged in 3D space to create 3D holographic like effects





Thin homogeneous signature

Foils with light shaping microstructure has been used to create very thin and homogeneous signature



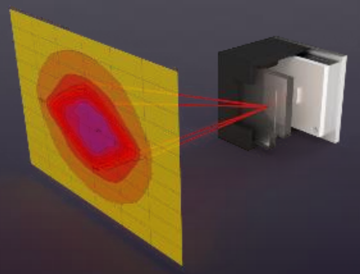
3D hologram in the lamp

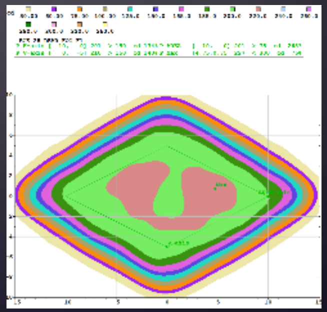
Foil with recorded hologram can be used to create levitating elements in the rear lamp

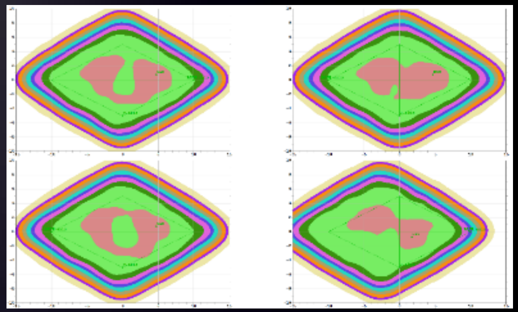
Injection Moulded Application Examples

Rear Fog

Only one inner lens with microstructure is placed in front of LED to create rear fog pattern. The biggest benefit seems to be the stability of the beam pattern to position of LED.

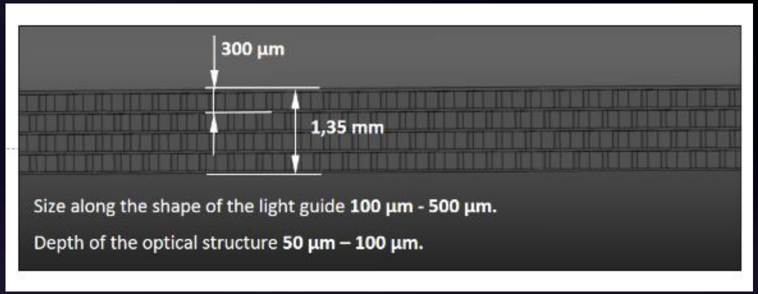






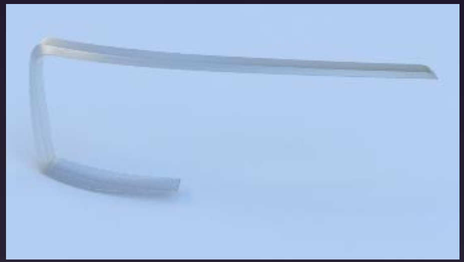
Light Pipe with Micro Optics

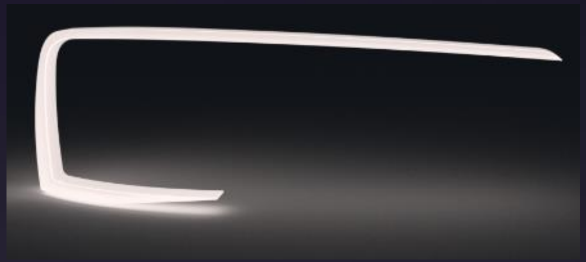
Instead of standard optical pattern (optical prisms), the micro optics was designed to decouple the light from the light pipe >> no visible optical structure on the light pipe.



3D Shape of Functional Inner Lens

Microstructure can improve the homogeneity/efficiency ratio for more powerful functions like DRL where the 3D styling is required together with excellent homogeneity.



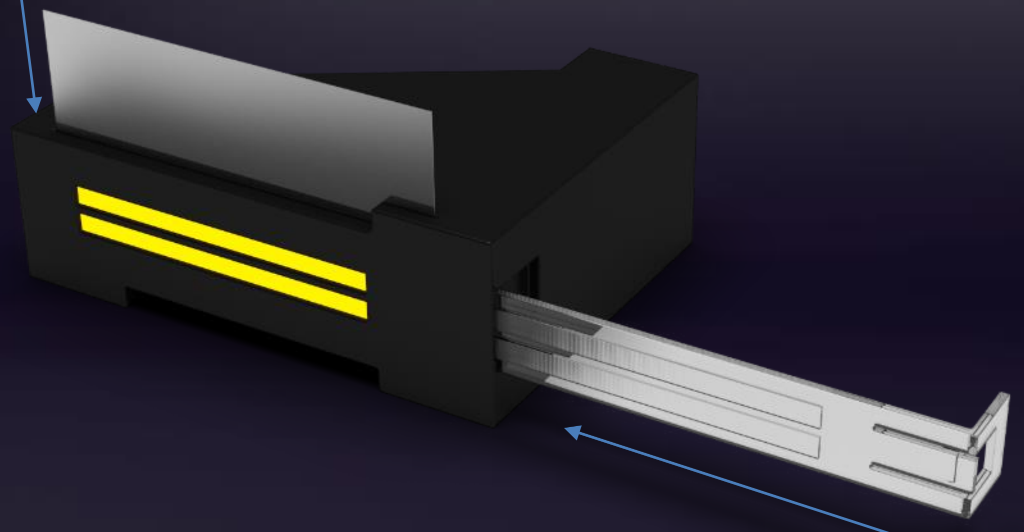


Optical efficiency and homogeneity comparison | Overview of experimental prototype

Straight light blade example was measured to compare homogeneity level and efficiency of various optical structures

Various microstructure foils were placed in front of the light blade

- 30 x 5 deg microstructure (30deg horizontal spread, 5deg vertical spread)
- 60 x 5 deg microstructure



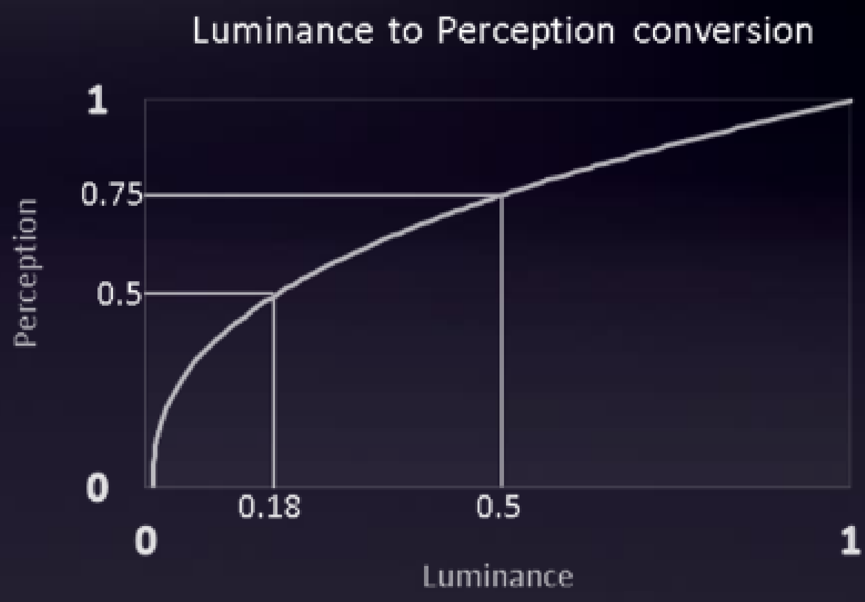
Various inner lenses were placed in front of the light blade

- Standard pillow optics
- Standard VDI36 graining
- Milky inner lens

VLS Homogeneity evaluation methodology

VLS internally developed software is used for homogeneity evaluation.

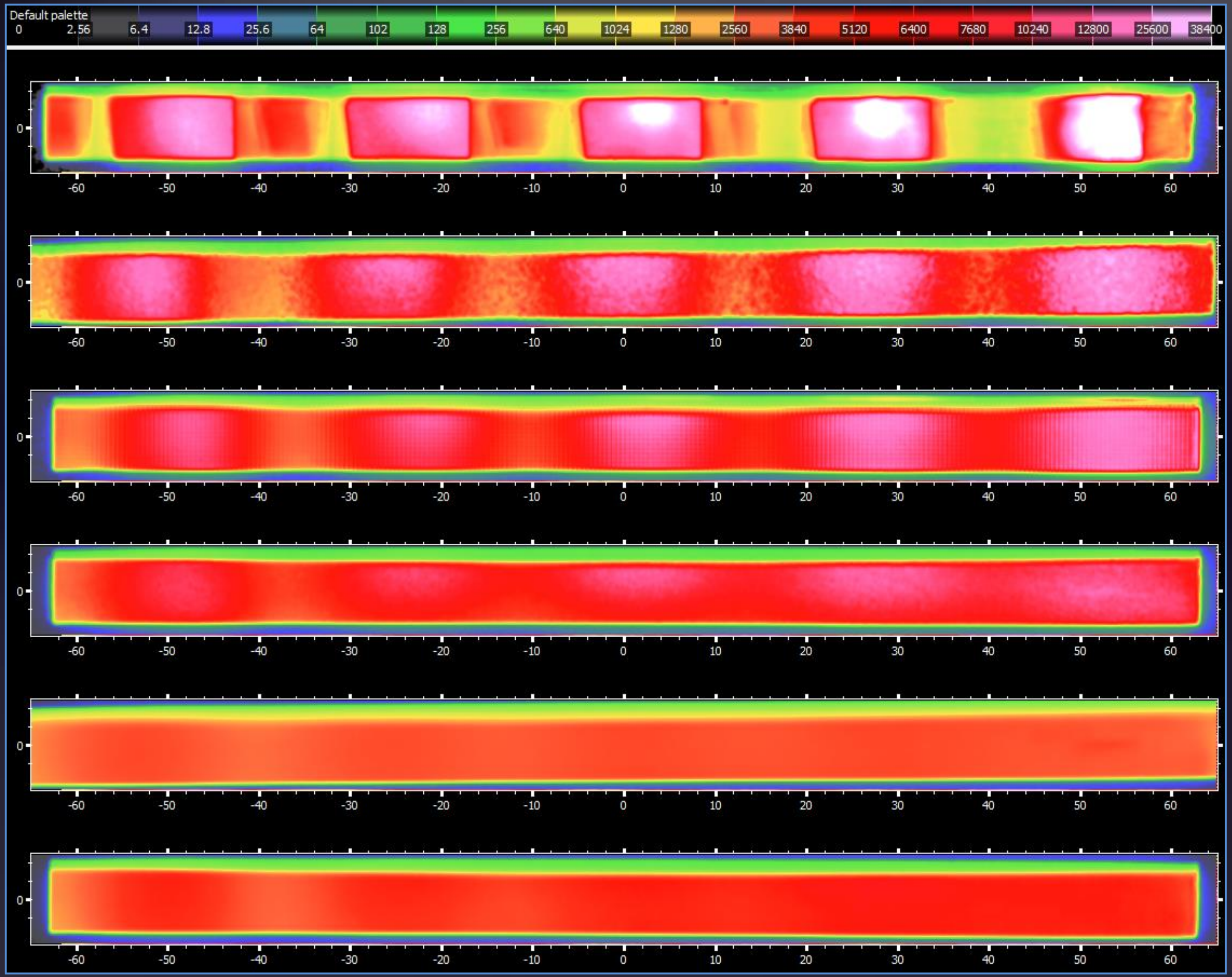
- Luminance values [cd/m^2] are converted to eye perception.



Optical efficiency and homogeneity comparison | Results

Straight light blade example measured to compare homogeneity level and efficiency of various optical structures

Luminance analysis



	Relative Efficiency	Homogeneity
Direct Light Blade	100%	36%
Standard VDI 36 graining	78%	62%
Standard optical pillows	67%	71%
Micro optics 30 x 5 deg	63%	85%
Milky inner lens	36%	87%
Micro optics 60 x 20 deg	38%	90%

! Similar homogeneity but different efficiency !

Optical efficiency and homogeneity comparison | What does it mean for LED's power?

Let's consider stop function as an example

	Light flux on LEDs	LEDs estimated power consumption	Power consumption saving
Milky inner lens	115 lm	4 W	-
Micro optics 60 x 20	105 lm	3.7 W	~ 8 %
Micro optics 30 x 5	65 lm	1.9 W	~ 50 %

POSSIBLE POWER CONUMPTION SAVING ABOUT ~50%

Summary

Wide range of different types of microstructures available

- Each system has advantages and strengths depending on application

Application can involve foils or implemented into tooling for injection molded parts

- Important to understand design strengths and limitations of the application for most cost effective solution
- Proprietary know-how and tools are required for effective design and manufacturing

Microstructures are critical for managing light in most efficient way

- Balance of homogeneity and optical efficiency
- Cost effective light source specification
- Power and weight optimization
- Design flexibility
- Package Space Reduction

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