ZUKUNFTSTAG

INNOVATIONS- UND WIRTSCHAFTSREGION SÜD

#bettertogether

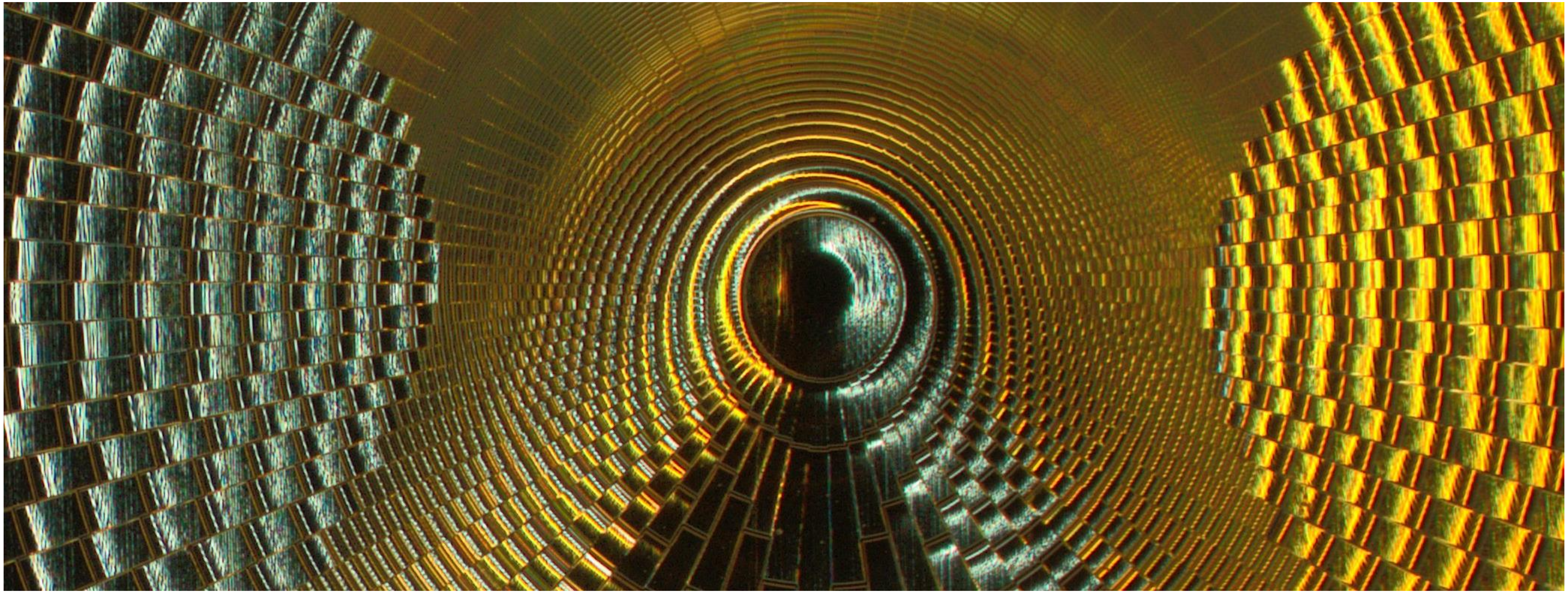
JOANNEUM RESEARCH

SFG NEUES DENKEN. NEUES FÖRDERN.

Das Land Steiermark
Wirtschaft, Tourismus, Regionen, Wissenschaft und Forschung

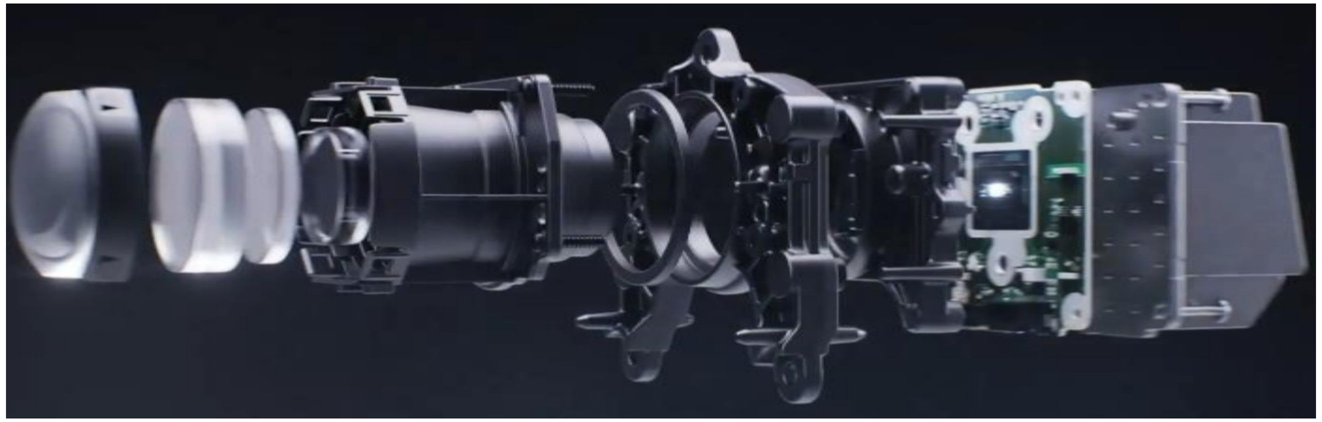
Licht in der Mobilität

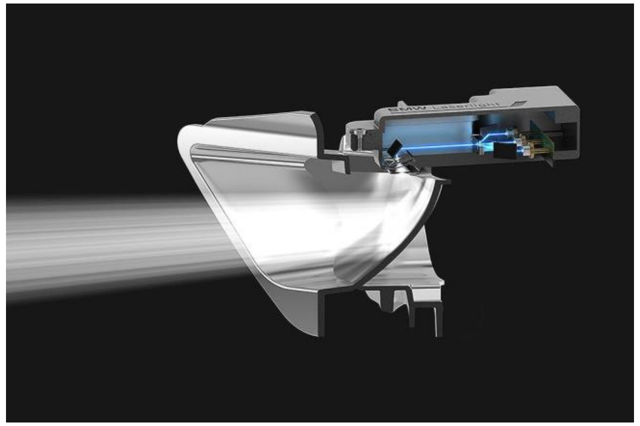
Freiform Mikro Optische Elemente - eine Lichtlösung

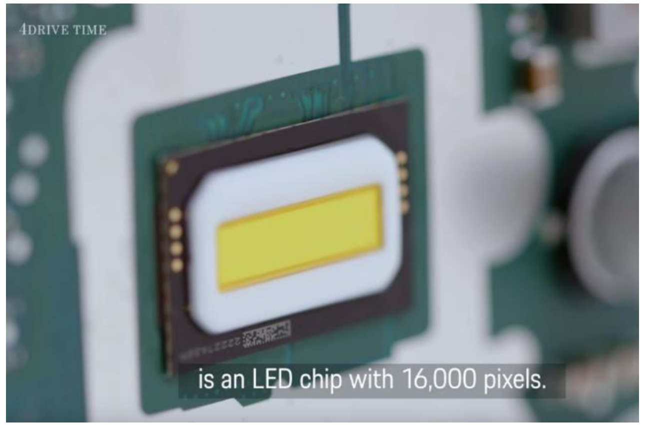


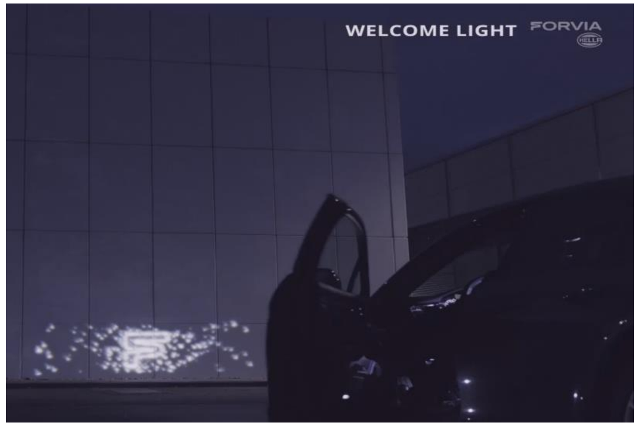
Trends in Mobility Lighting

- Headlamps: Laser vs. HD-Matrix-LED









https://www.carsales.com.au/editorial/details/laser-lighting-to-disappear-146985/ https://www.youtube.com/watch?v=0HdyygWooqk https://www.hella.com/techworld/de/Services/Automotive-mega-trends-95857/ https://zkw-group.com/home/produkte-und-innovationen/die-zukunft-des-lichts/

Trends in/Future of Mobility Lighting

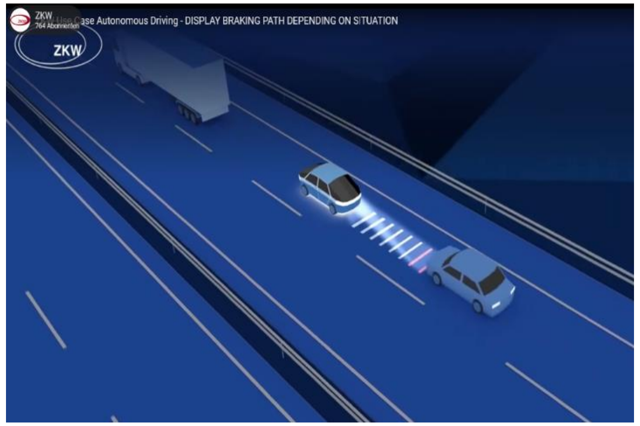
- Interior - Car

https://www.volkswagen.at/modelle/technologie/fahrzeugbeleuchtung/ambientebeleuchtung

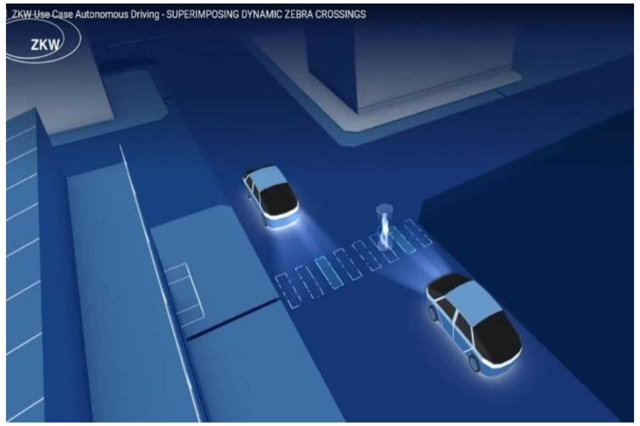
- Safety

https://lichtnet.de/news/2014/10/01/leuchtende-innovation-im-untergrund/

- Braking path



- Zebra crossing



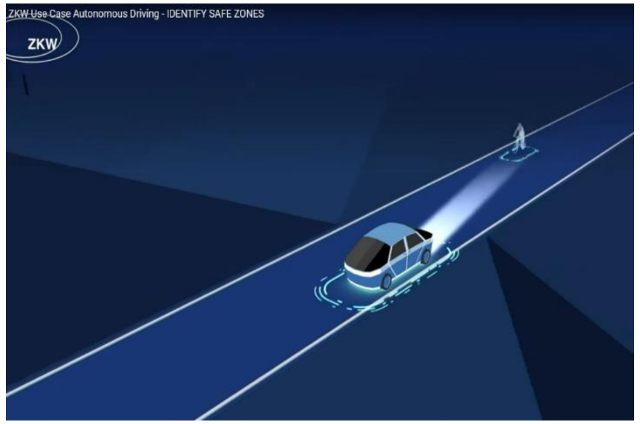
- Interior - Train

https://lichtnet.de/news/2014/10/01/leuchtende-innovation-im-untergrund/

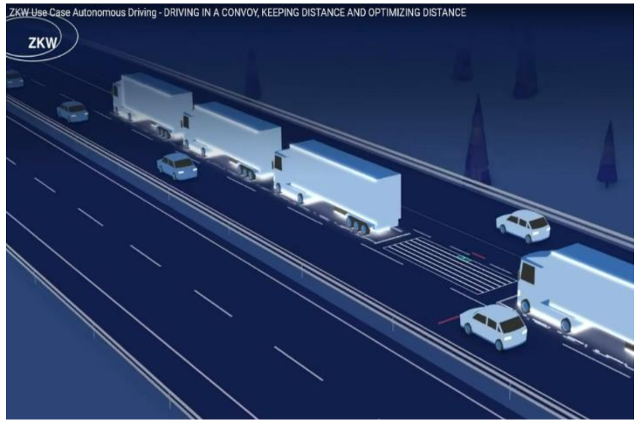
- OLED Rear light

https://www.angurten.de/news/3691-oled-2-0-im-audi-q6-e-tron-dynamische-lichtsignatur.html

- Safety Vehicle zone



- Convoi driving



https://zkw-group.com/home/produkte-und-innovationen/die-zukunft-des-lichts/

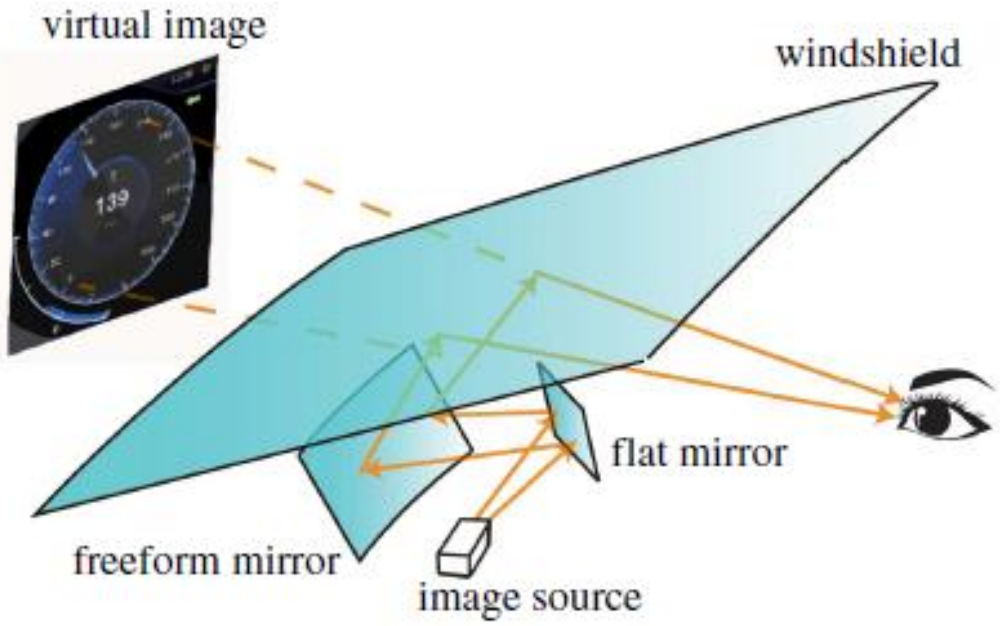
Motivation: Free-Form Optics

Due to their nonrotational features, **free-form optics can have almost an arbitrary surface** and therefore offer **incredibly high degrees of freedom** compared to spherical optics.

These high degrees of freedom e.g. allow the generation of **tailored irradiance or radiant intensity distributions** with a maximum of system performance or **even combining the functionalities of different optical elements** in one free-form surface. Free-form optics has been a **very hot topic of research and development** over the last decades and has found **wide application in many different fields.**

Exemplary Application Fields

Automotive:



Wei, S., Fan, Z., Zhu, Z., & Ma, D. (2019). Design of a head-up display based on freeform reflective systems for automotive applications. *Applied optics*, *58*(7), 1675-1681.

Motivation: Free-Form Optics

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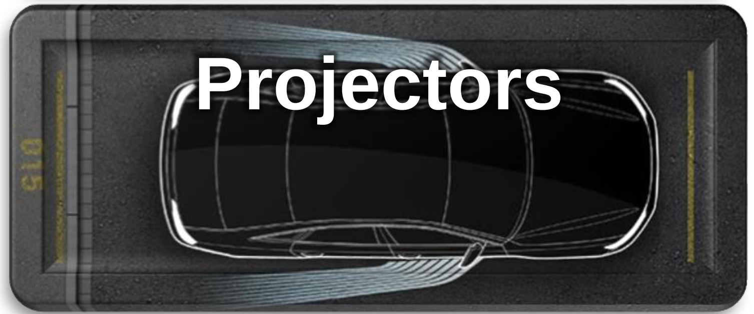
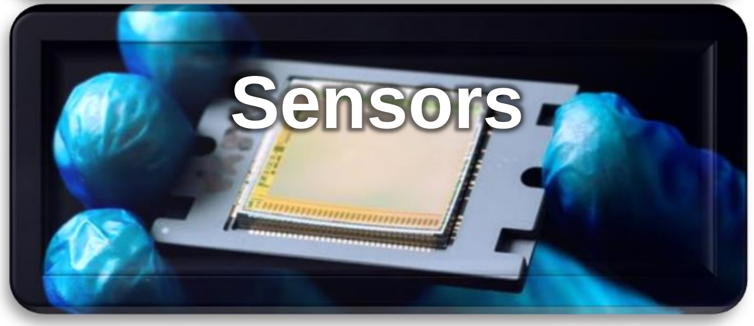
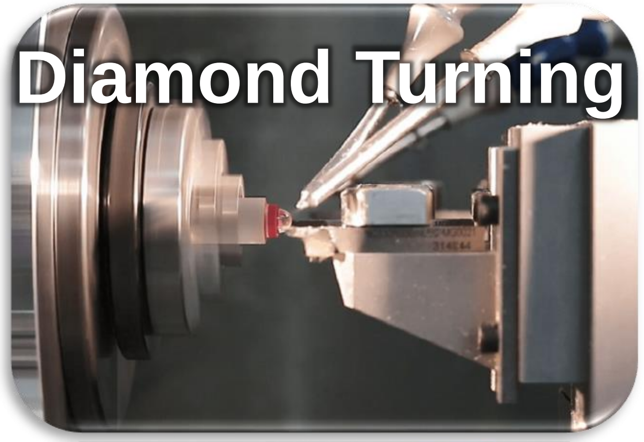
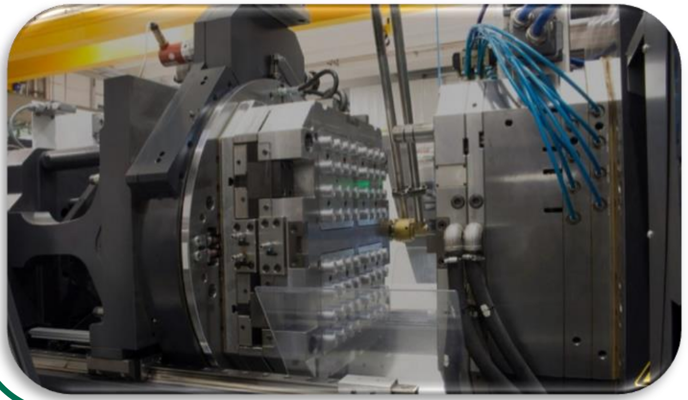




Origination methods of optics and freeform optics:



Replication of the optics with injection molding:



Our Vison, FF-MOEs:

"Free-Form Micro Optical Elements"

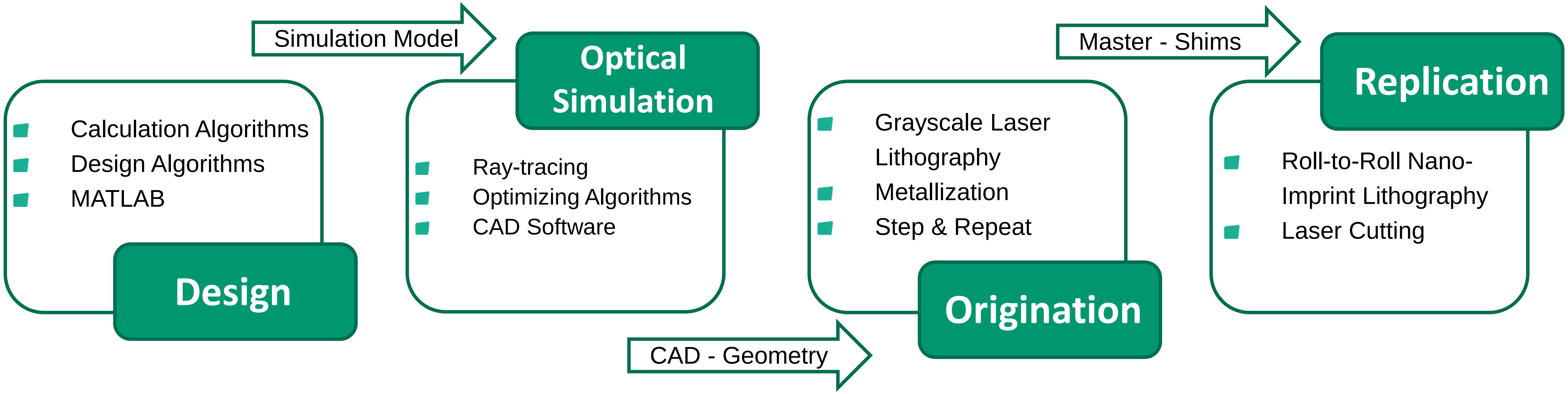
A scalable, cost- and resource-effective microstructure approaching light control abilities of bulky freeform optics.

- Scalable height in the µm regime.
- Significantly lower material consumption.
- Bio based resigns.
- Compatible with injection molding.
- Enabling new cost-effective fabrication methods:
  - Grayscale Laser Lithography
  - Step & Repeat
  - Roll-to-Roll Nano imprint Lithography

„Printing optics like newspapers"

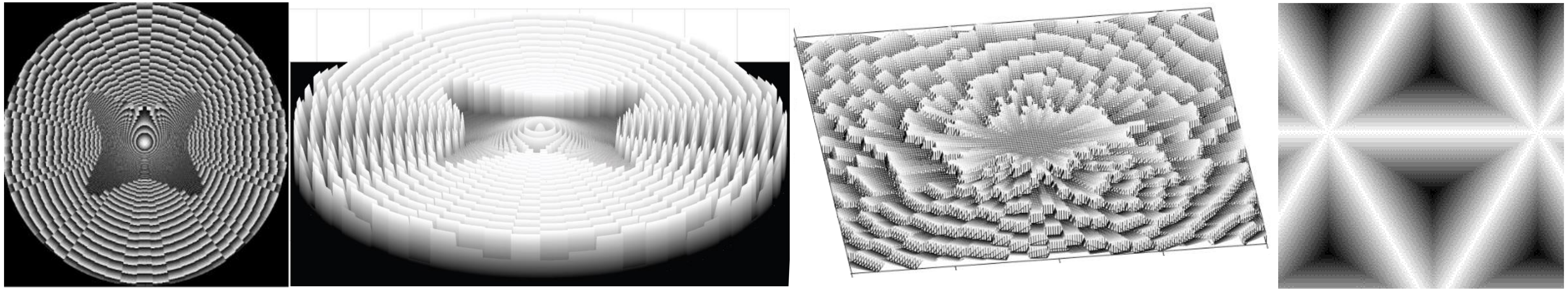
Value Chain for Developing Free-Form Micro Optical Elements @ JR Materials

- Our Value Chain comprises all necessary steps from the idea to the manufactured structures on a foil. In detail, it can be subdived into the **Design**, the **Optical Simulation**, the **Origination** and the **Replication** process.



Value Chain for Developing Free-Form Micro Optical Elements @ JR Materials

- During the **Design Process** the shape of the free-form micro optical elements is calculated using self-developed algorithms. Additionally a **Simulation Model** of all relevant optical parts of the system is build and is passed to the next process.



Design

Simulation Model

Design
- Calculation Algorithms
- Design Algorithms
- MATLAB

Optical Simulation
- Ray-tracing
- Optimizing Algorithms
- CAD Software

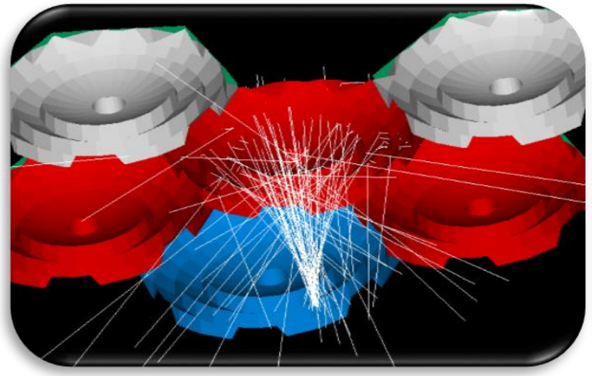
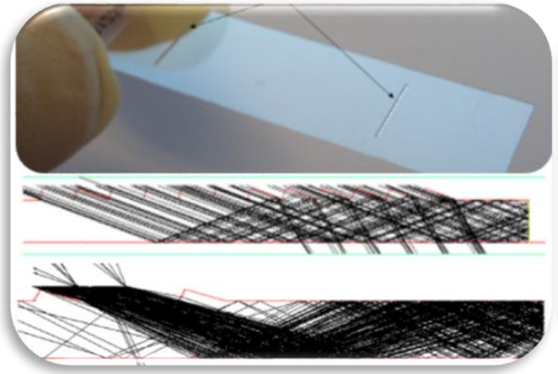
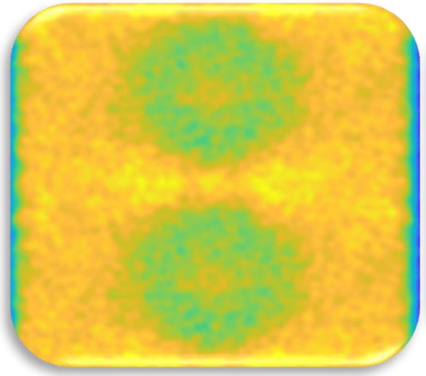
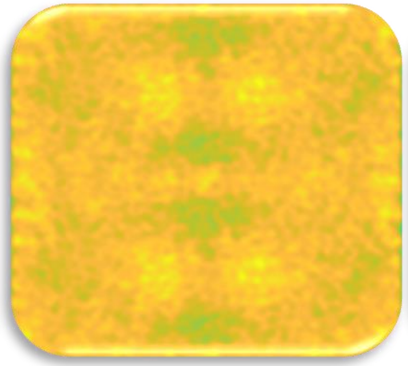
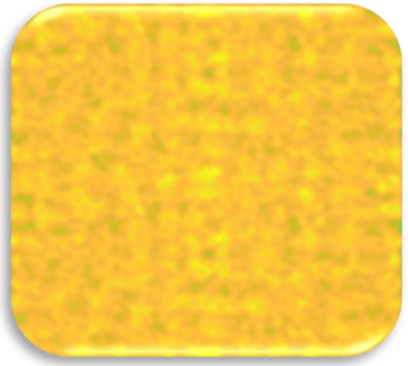
Origination
- Grayscale Laser Lithography
- Metallization
- Step & Repeat

Replication
- Roll-to-Roll Nano-Imprint Lithography
- Laser Cutting

Value Chain for Developing Free-Form Micro Optical Elements @ JR Materials

Optical Simulation is used to **verify the optical functionality** of the calculated free-form micro optical elements by means of ray-tracing simulations. Furthermore a **Iterative Feedback Loop** between design and optical simulation is used to **enhance the functionality of the structures.** After completion of this step, a **CAD geometry** of the structures is transferred to the next process.

Optical Simulation

Design

- Calculation Algorithms
- Design Algorithms
- MATLAB

Optical Simulation

- **Ray-tracing**
- **Optimizing Algorithms**
- **CAD Software**

Origination

- Grayscale Laser Lithography
- Metallization
- Step & Repeat

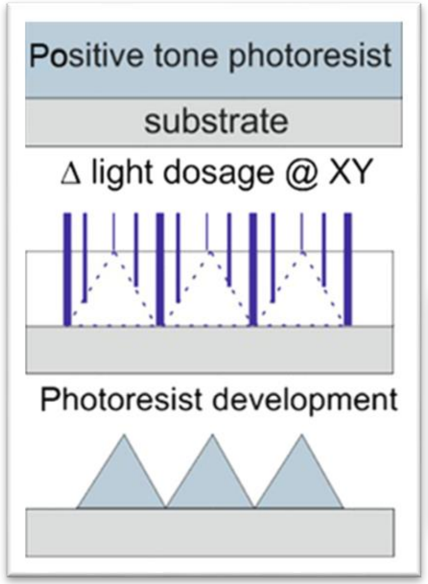
Replication

- Roll-to-Roll Nano-Imprint Lithography
- Laser Cutting

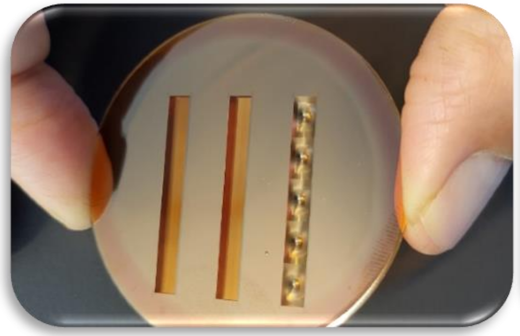
Iterative Feedback Loop

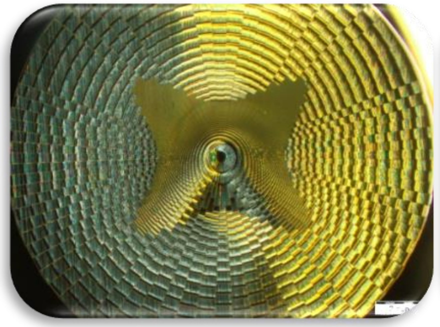
CAD - Geometry

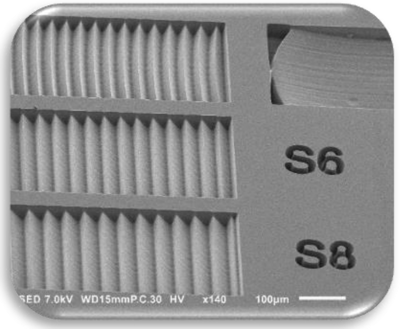
Value Chain for Developing Free-Form Micro Optical Elements @ JR Materials



In the Origination process, CAD geometry is converted to a virtual photomask with light dosage representing each z-value at every x,y position. A laser applies these doses at the respective positions to a positive photoresist, which becomes soluble after light exposure and forming structures after chemical development by removing exposed areas. The originated structures are nickel-plated to form a solid metal master for tooling.







Origination

Design

- Calculation Algorithms
- Design Algorithms
- MATLAB

Optical Simulation

- Ray-tracing
- Optimizing Algorithms
- CAD Software

Origination

- **Grayscale Laser Lithography**
- **Metallization**
- Step & Repeat

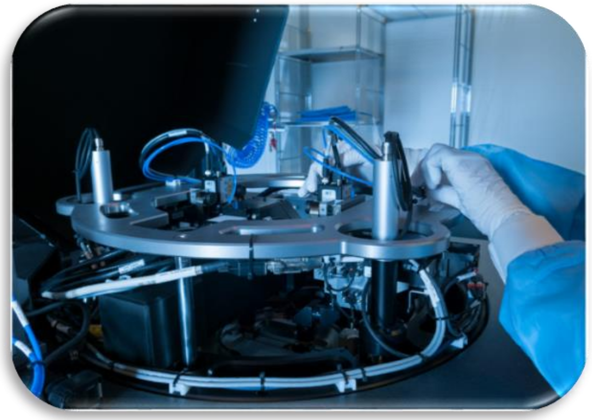
Master - Shims

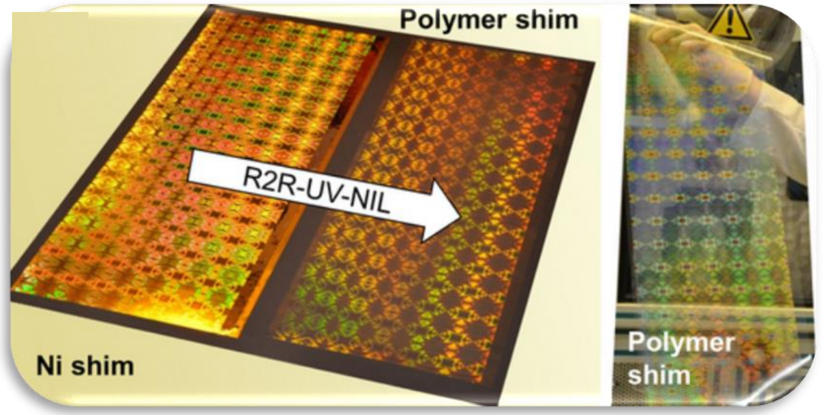
Replication

- Roll-to-Roll Nano-Imprint Lithography
- Laser Cutting

Value Chain for Developing Free-Form Micro Optical Elements @ JR Materials

Step & Repeat (S&R) UV-NIL is a key tooling technology for R2R. To **upscale FF-MOE**, successive UV-imprints at low pressure and room temperature can fill large areas either by replicating or combining FF-MOE cells, **reducing master fabrication** costs. **Seamless pattern** upscaling vital for many applications, requiring precise definition of active pattern areas, stable imprinting processes, accurate machine positioning, and uniform residual layer thickness control.





Origination

Master - Shims

Design

- Calculation Algorithms
- Design Algorithms
- MATLAB

Optical Simulation

- Ray-tracing
- Optimizing Algorithms
- CAD Software

Origination

- Grayscale Laser Lithography
- **Metallization**
- **Step & Repeat**

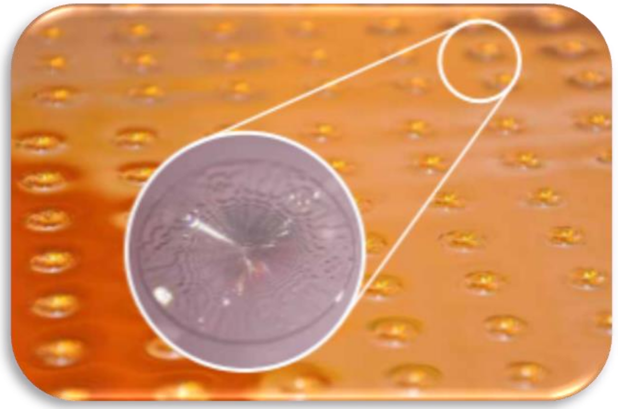
Replication

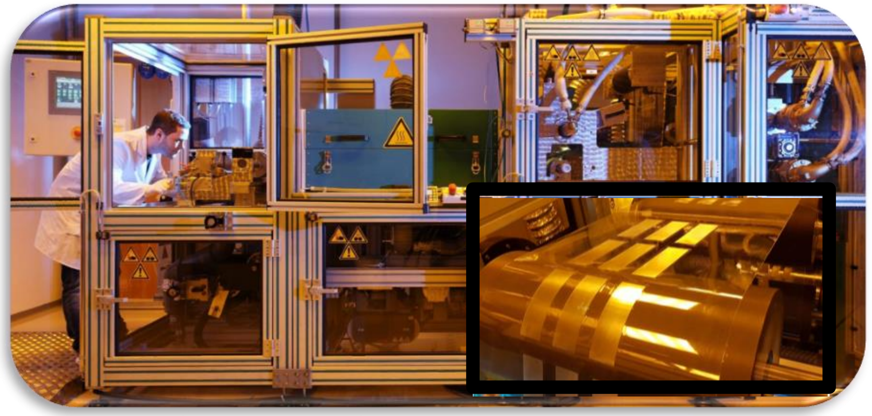
- Roll-to-Roll Nano-Imprint Lithography
- Laser Cutting

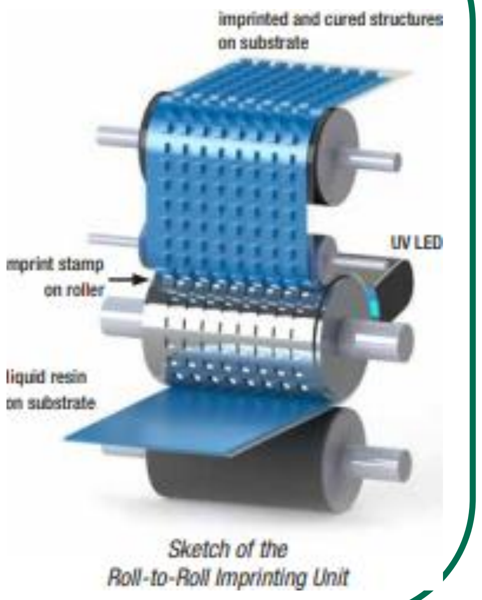
Value Chain for Developing Free-Form Micro Optical Elements @ JR Materials

Roll-to-roll nanoimprint lithography (R2R) has demonstrated **high-resolution micro- and nanostructures via imprinting** with length scales far below those associated with the classic manufacturing technologies of plastics (e.g. injection molding)

Replication







Design

- Calculation Algorithms
- Design Algorithms
- MATLAB

Optical Simulation

- Ray-tracing
- Optimizing Algorithms
- CAD Software

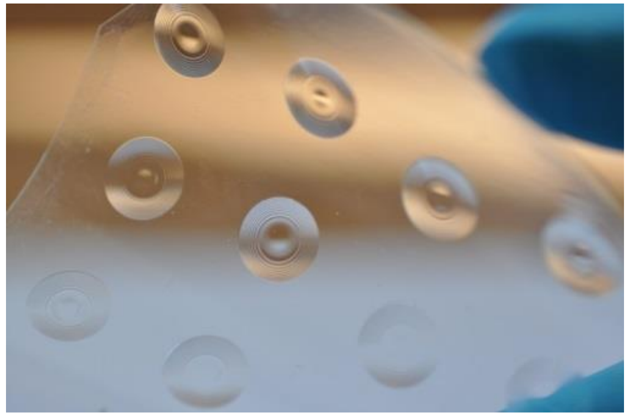
Origination

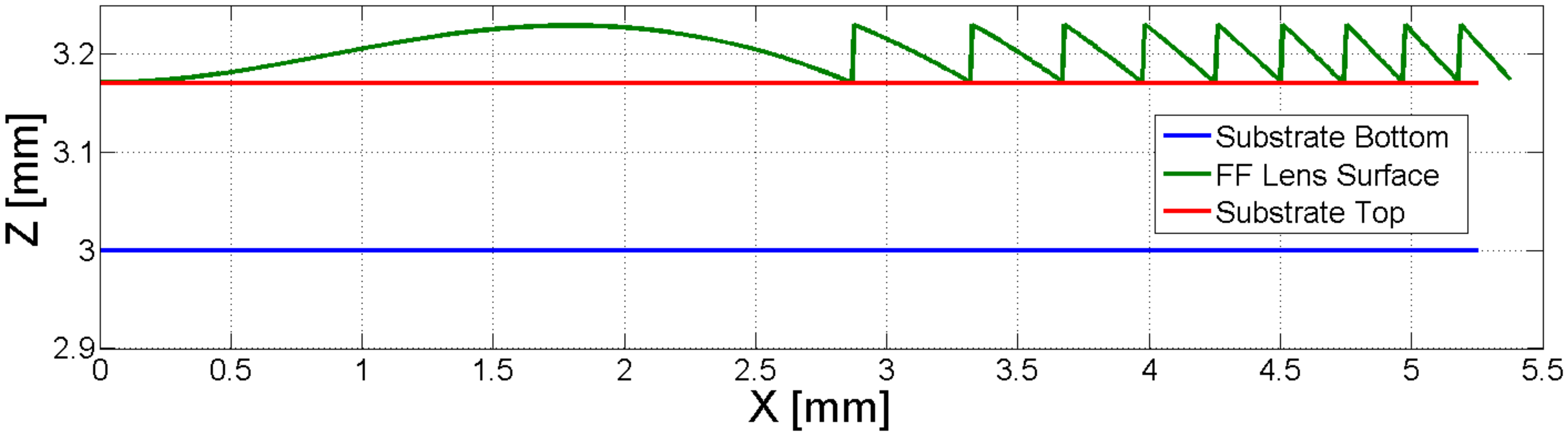
- Grayscale Laser Lithography
- Metallization
- Step & Repeat

Replication

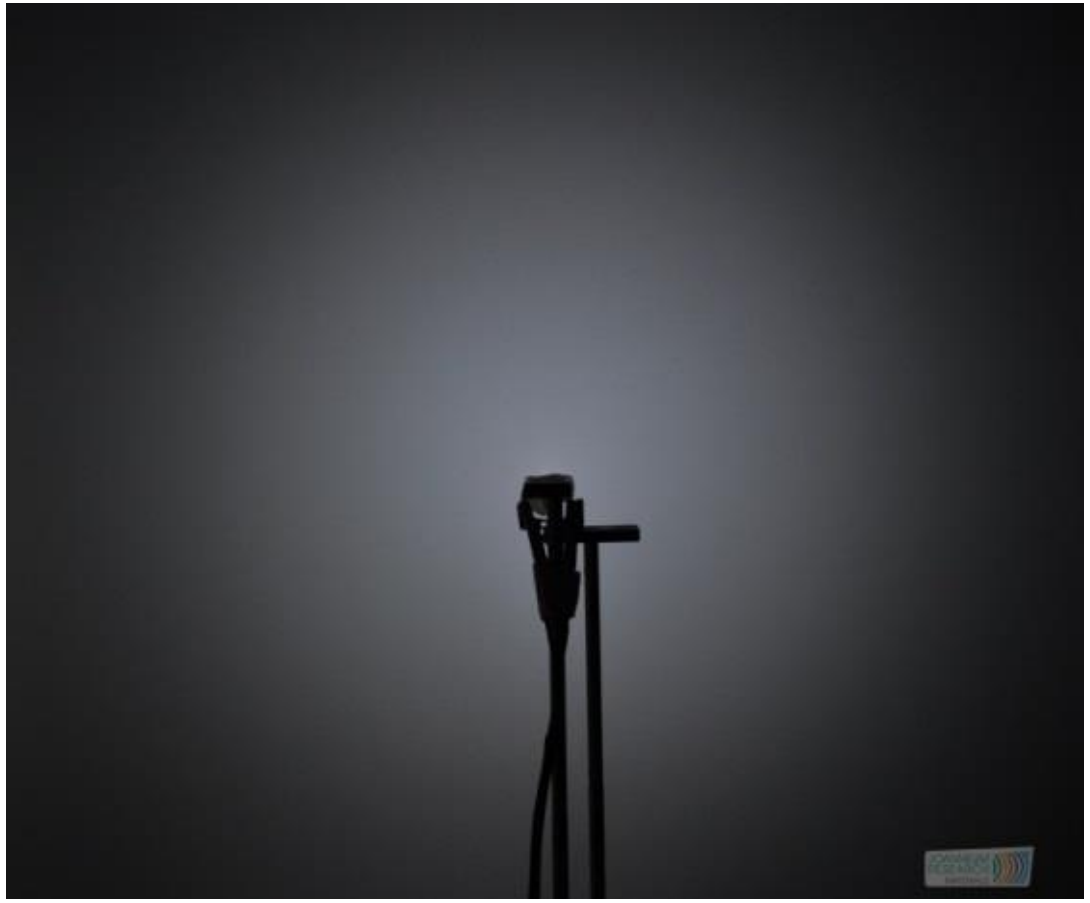
- **Roll-to-Roll Nano-Imprint Lithography**
- **Laser Cutting**

Example: Realizing an optic which is homogenously redistributing the emitted light of an LED into a circular area.





Without FF-MOE



With FF-MOE

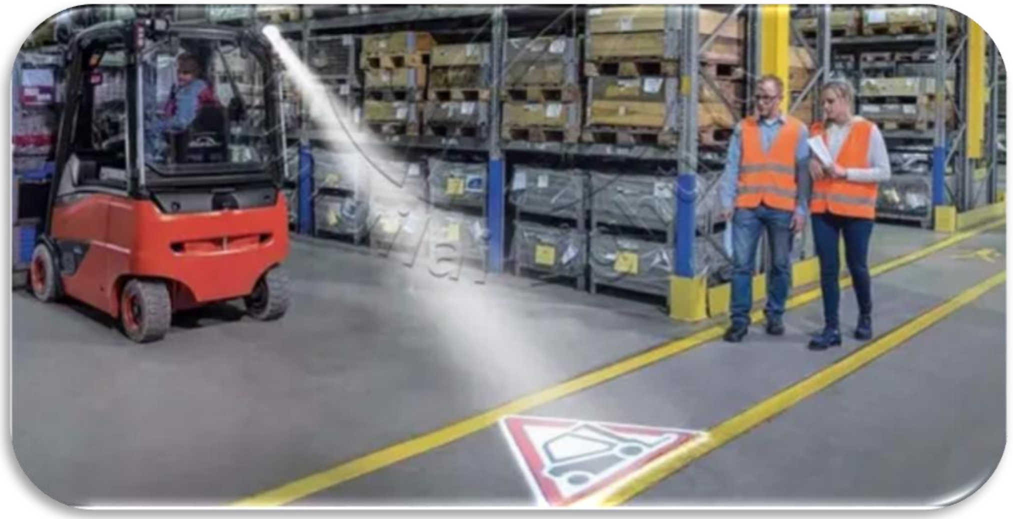
Logo Projection

Feasibility study for evaluating the potential of FF-MOEs for **Logo/Signal projection**, using a single plane with structures :

Differences between FF-MOE approach and image projection:

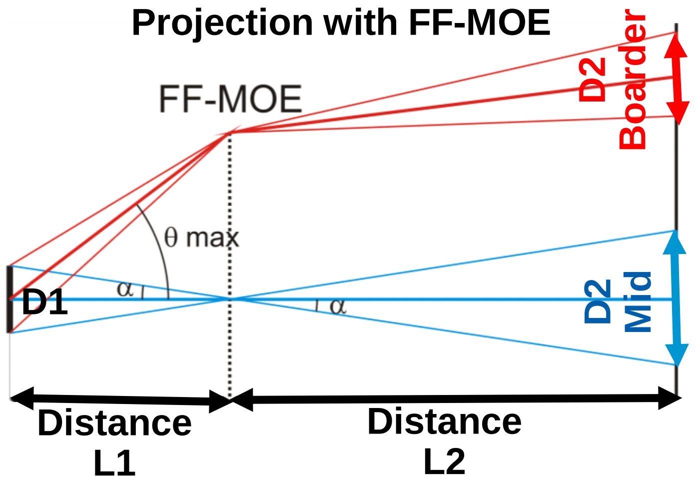
- FF-MOEs redistributing the light emitted from the LED to **create of defined light/dark areas**.
- Areas of the FF-MOEs match areas of the illumination pattern, enabling **higher resolution at the edges**.
- **A complex optical system is replaced by a single optical component.**

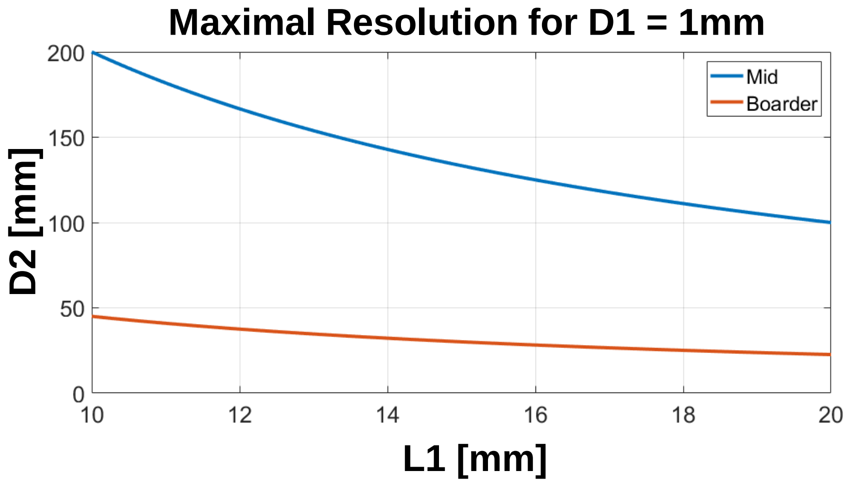
Analysis depended on the lateral extent of the light source (D1) and its distance from the FF-MOEs (L1). L2 = 2m, θmax = 60° for all results showed.



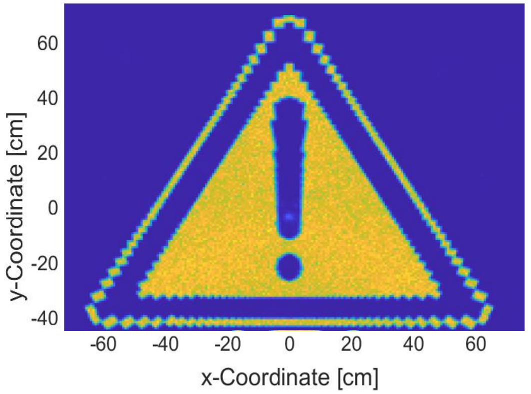
Motive

Light/Dark Areas

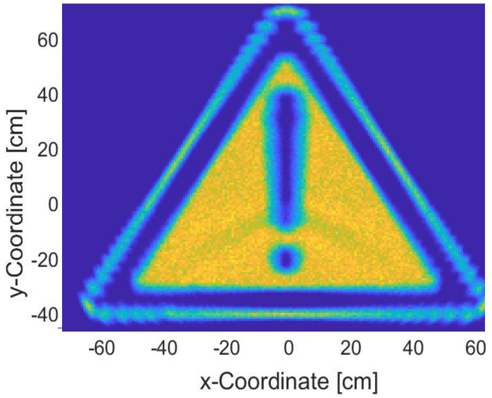




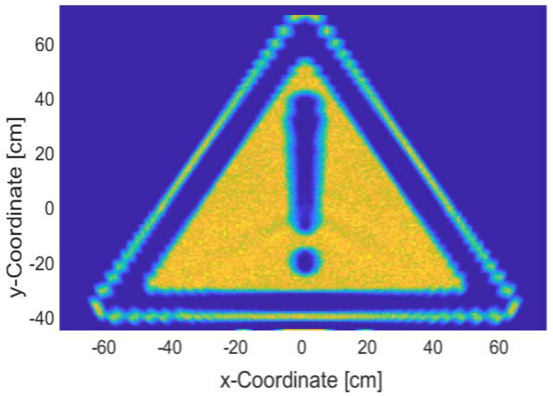
D1= 0.1 mm, L1= 10 mm



D1= 0.5 mm, L1= 10 mm



D1= 0.5 mm, L1= 15 mm



Low Beam System

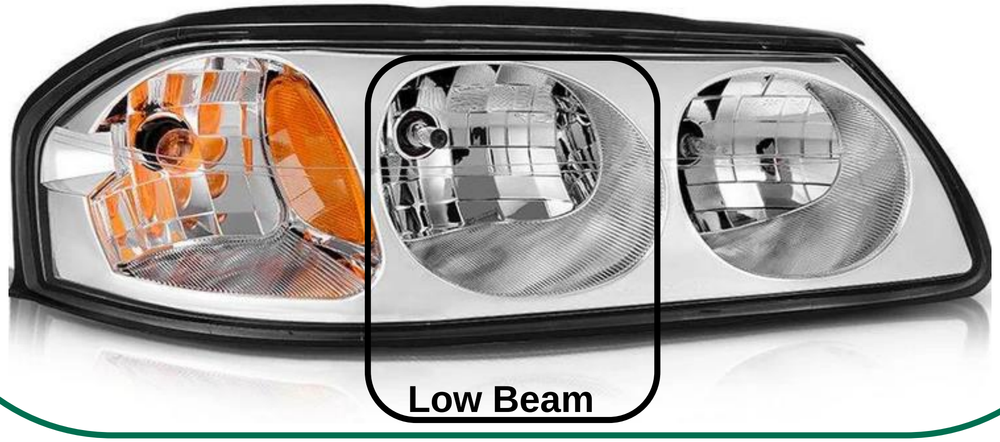
Project SusMat4CarLight: Design of an optical system for a **low-beam headlight module using FF-MOEs**.

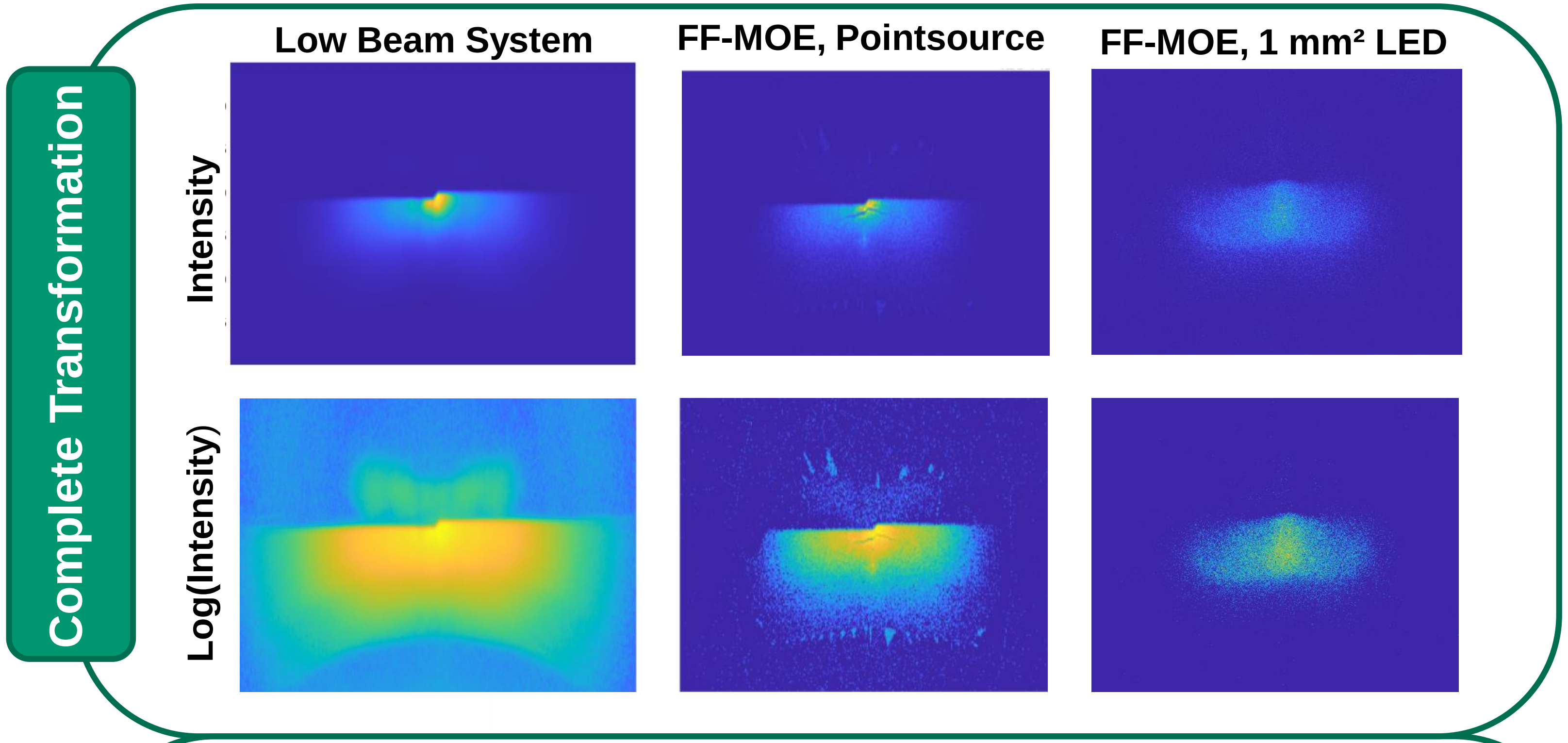
Challenging Light Distribution:

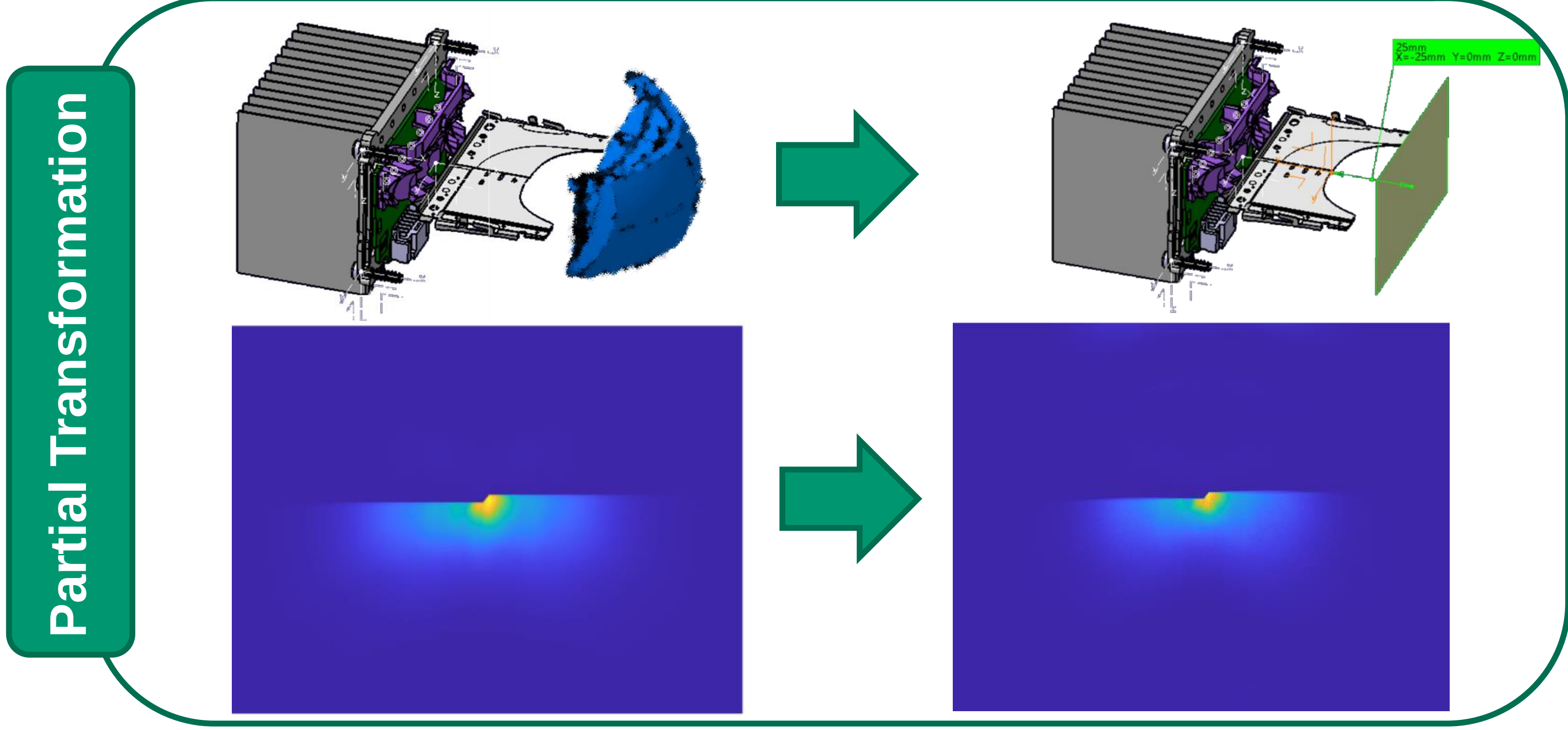
- Strong asymmetries (top vs. bottom), with a very wide horizontal spread and a very narrow vertical spread.
- Sharp cut-off line, with a maximum gradient of 0.3 to 0.35 degrees in the central region.
- High concentration of light in the central area (horizontal ±10 degrees, vertical 0–5 degrees).

A **complete transformation of the optical system into a FF-MOE on a plane was not feasible** due to these challenges, especially the sharpness of the cut-off line when using extended LEDs.

Replacing the thick projection lens with an FF-MOE, however, appears promising.





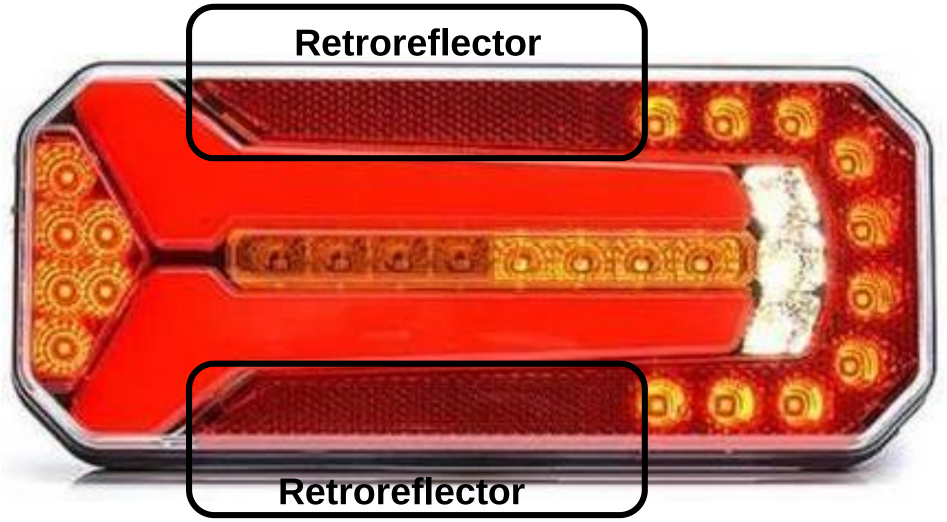


Retroreflectors

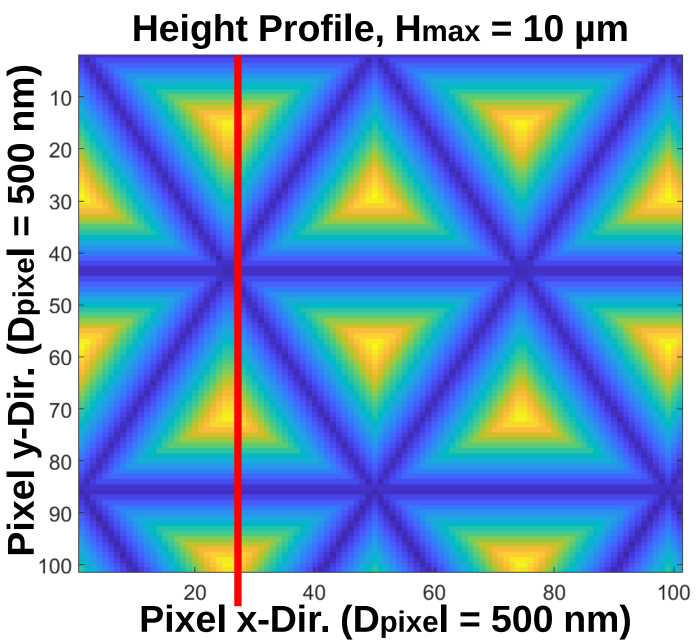
Design and fabrication study of tiny **retroreflector microstructures** — pyramids with three surfaces forming 90° angles to each other — with the following parameters:

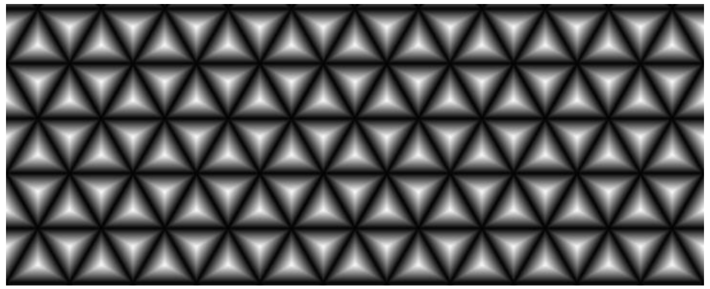
- Pixel resolution of 500 nm .
- Maximum structures **height 10 µm**.
- Structured **area of 1 cm²**.
- Around **0.385 million pyramids** on the 1 cm² area.
- **Coated with aluminium.**

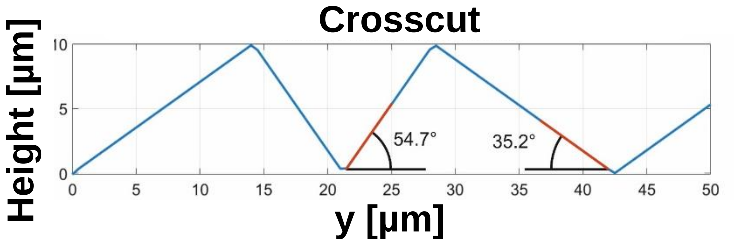
A retroreflector reflects incoming light back in the direction of origin, independent of incidence angle relative to the surface. Normally the structures are visible, but with a **height of 10 µm the structure looks homogenous**.



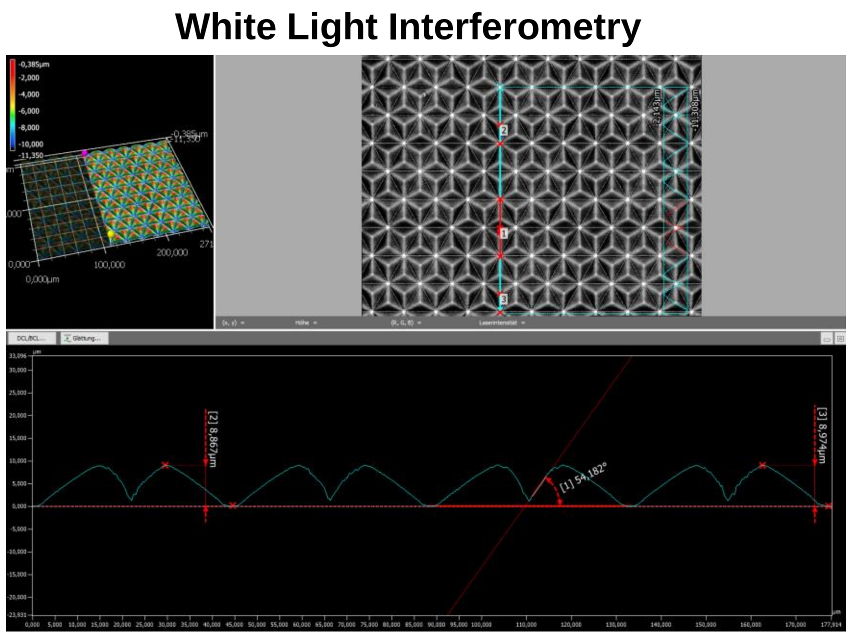
Design







Measurement

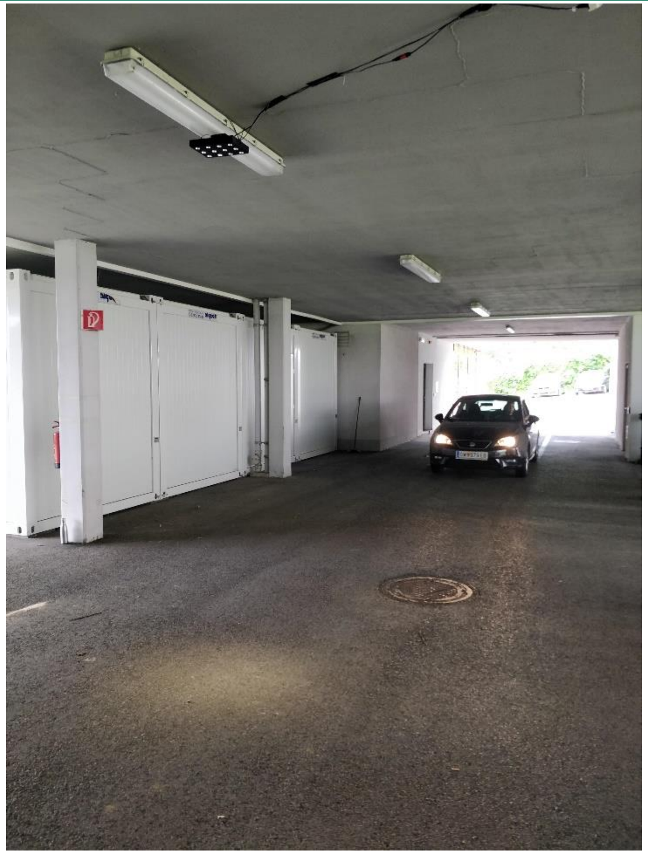


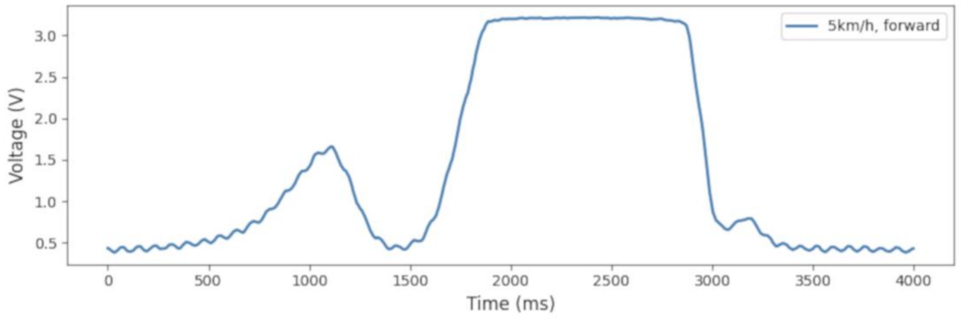
Outlook: LED as Sensor in Traffic Infrastructure

With the approach of operating LEDs not only as a light source but also as a photosensitive element, the role of lighting in the traffic infrastructure can be enhanced, towards the vision that every lighting fixture in the traffic infrastructure becomes a fully-fledged data point.

By applying this approach, the same components can be used for two purposes without this duality being perceived by human observers or negatively affecting the light quality, rendering ecological and economic benefits.

Please come and visit us at the Poster Session





Danke!

















Danke für Ihre Aufmerksamkeit!