

WAFER-LEVEL MANUFACTURING OF MICRO-OPTICS

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WAFER-LEVEL MANUFACTURING OF MICRO-OPTICS

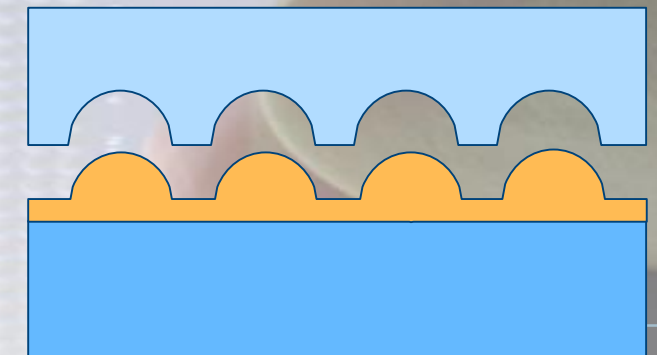
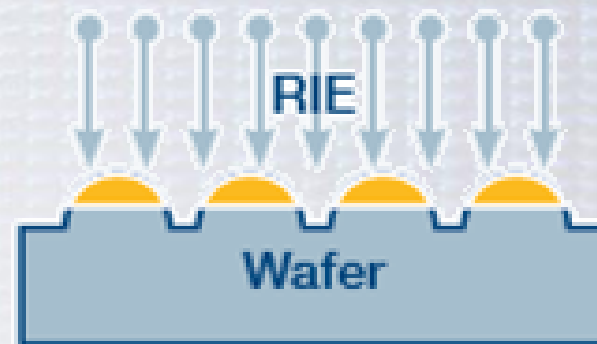
or ... *TO ETCH OR TO IMPRINT* MICRO-OPTICS ?

IS THIS REALLY THE QUESTION?

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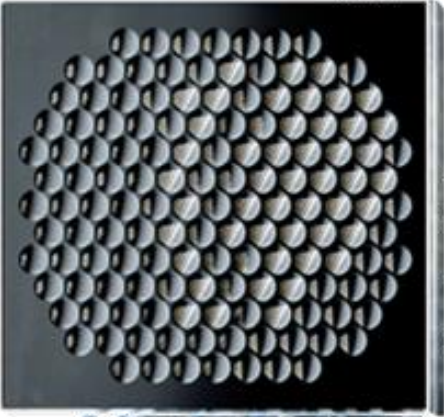
8" (200mm) Wafer Cleanroom Fab & Imprint Lithography Production

- + **Founded 1998**
- + **Refractive microoptics**
- + **Diffraction microoptics**
- + **Worldwide client base in data/telecom, metrology, semiconductor, instruments**
- + **Part of the SUSS MicroTec Group**

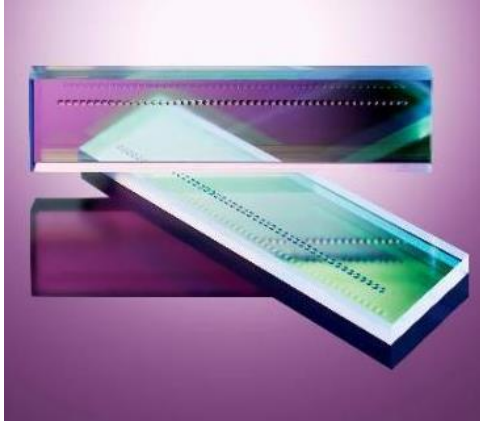
IATF 16949
Automotive Qualified Imprint Production

PRODUCTS AND MARKETS

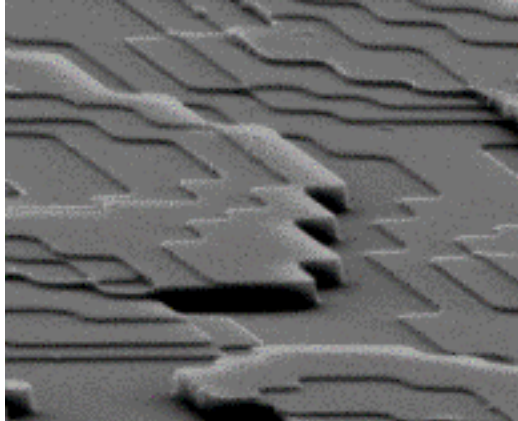
+ AUTOMOTIVE



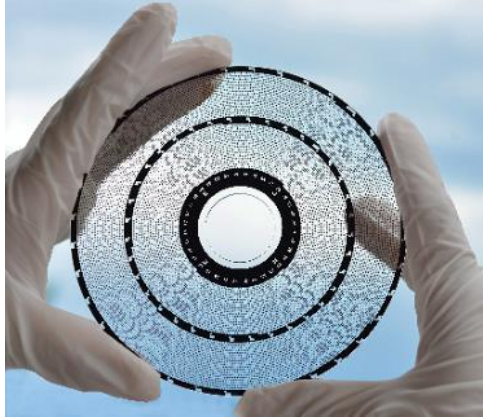
+ TELE/DATACOM



+ SEMICONDUCTOR

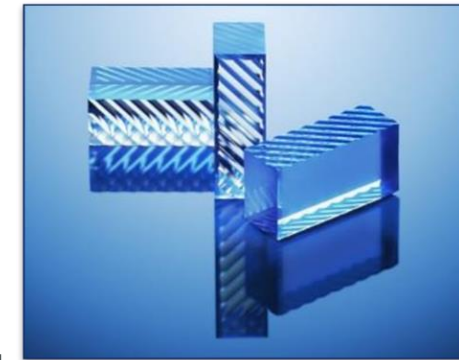
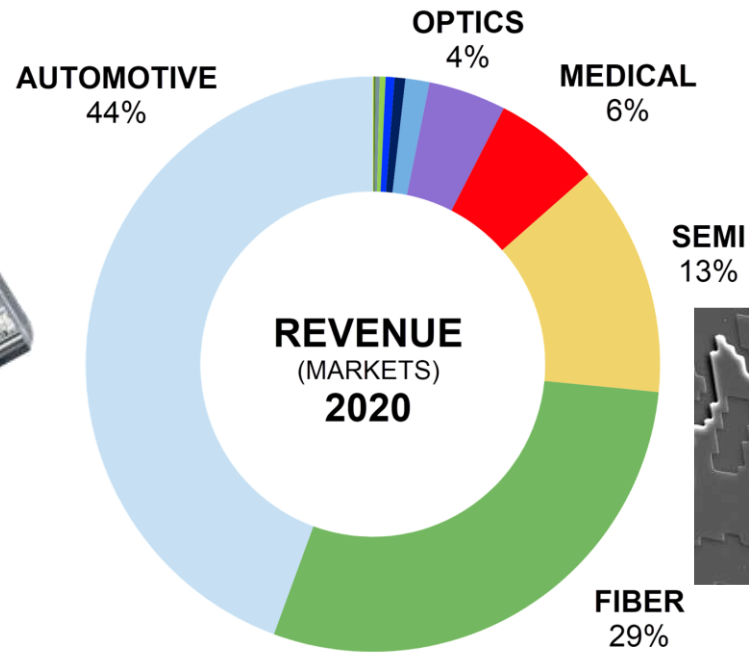
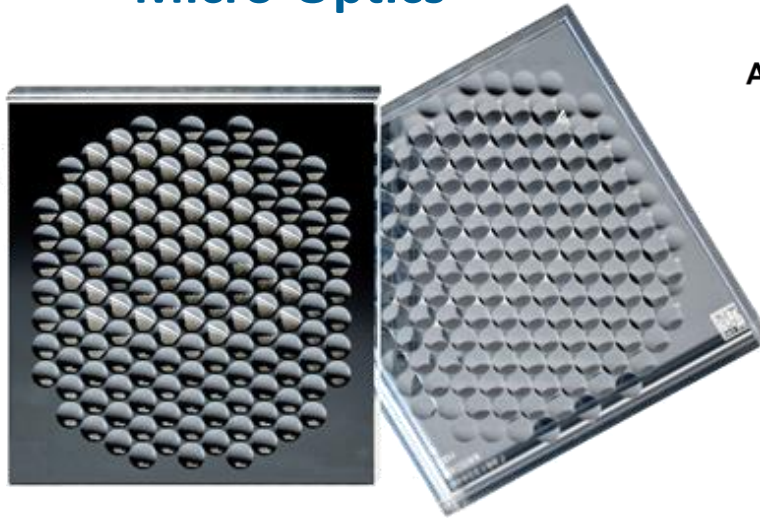


+ MEDICAL

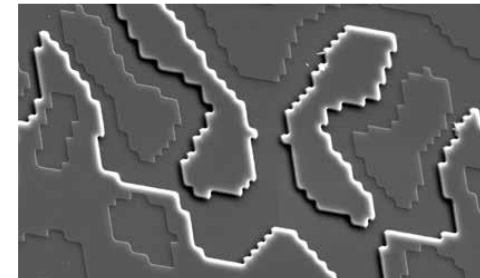
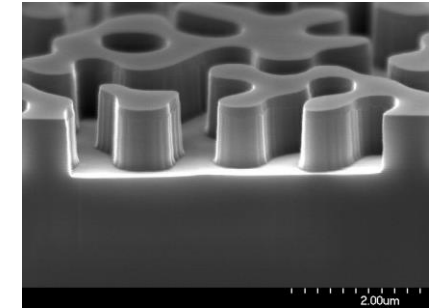


AUTOMOTIVE, LASERS, DATACOM, TELECOM, FIBERS, PICS, ...

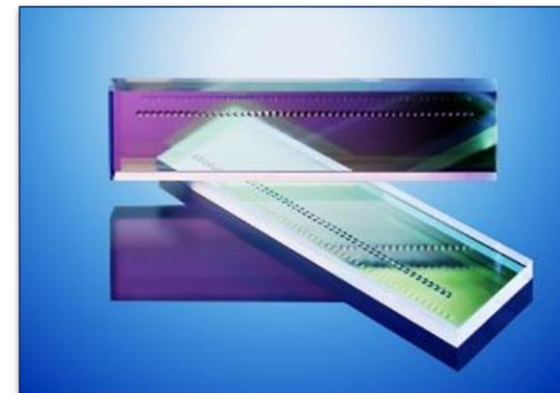
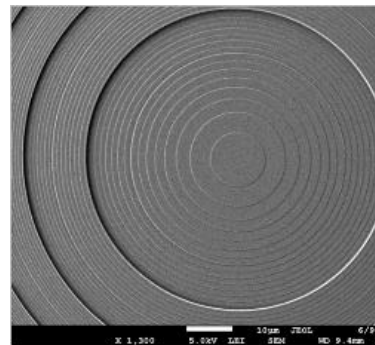
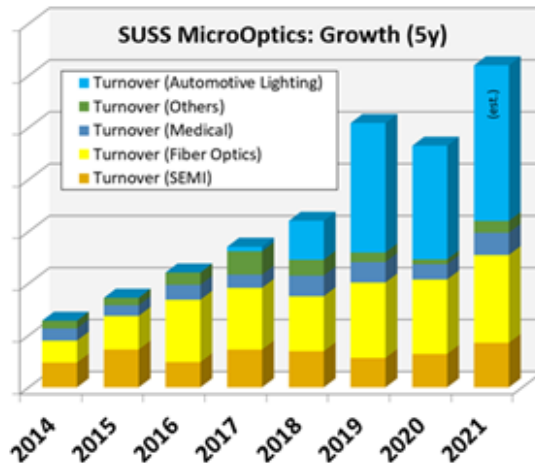
Imprinted Micro-Optics

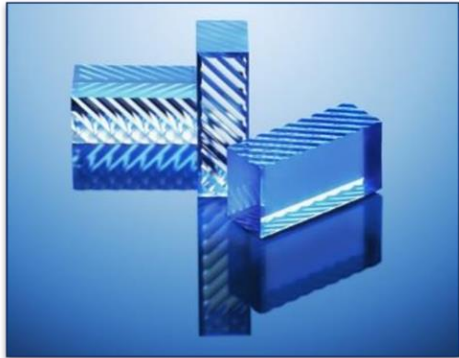
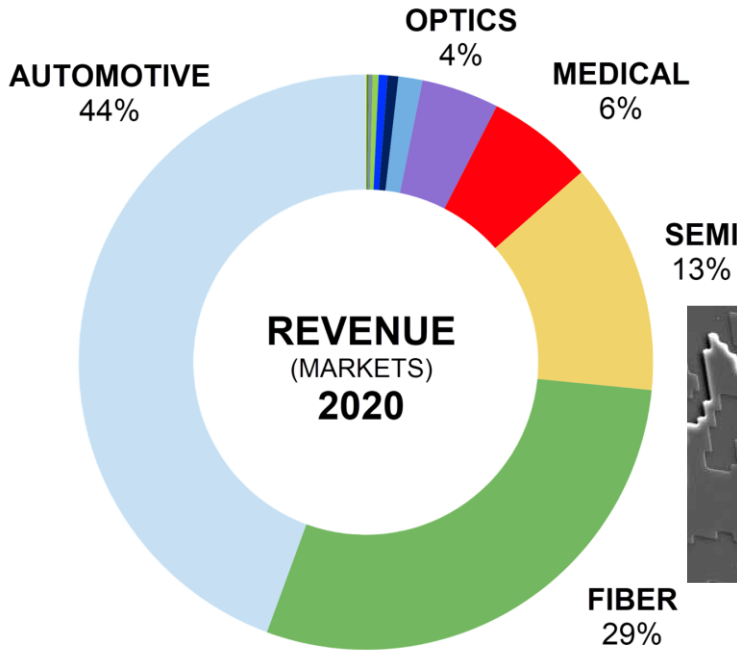


Etched Micro-Optics

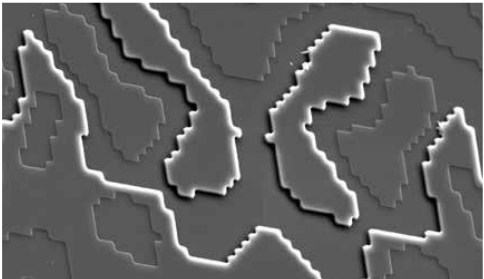
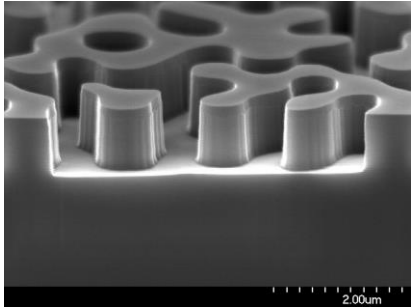


FIBER
29%

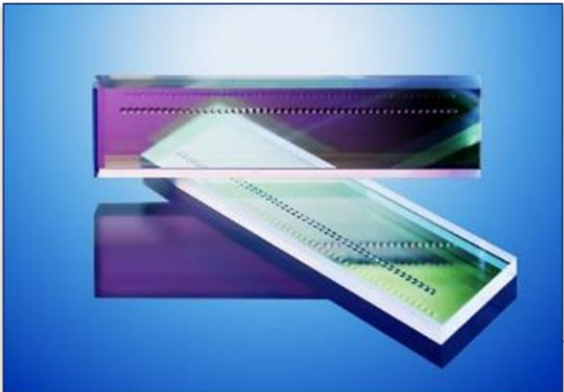
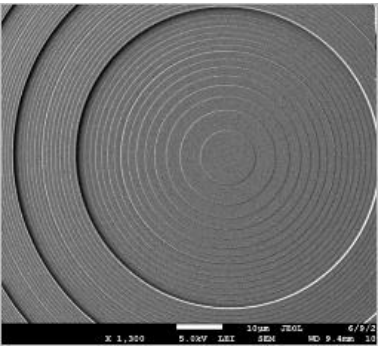
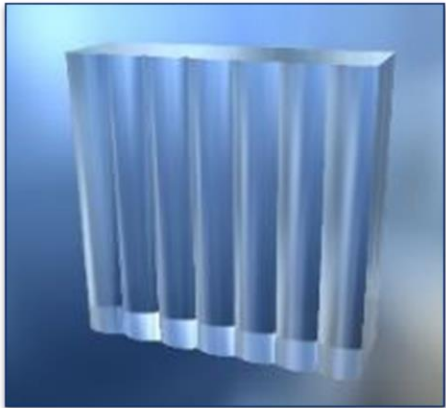




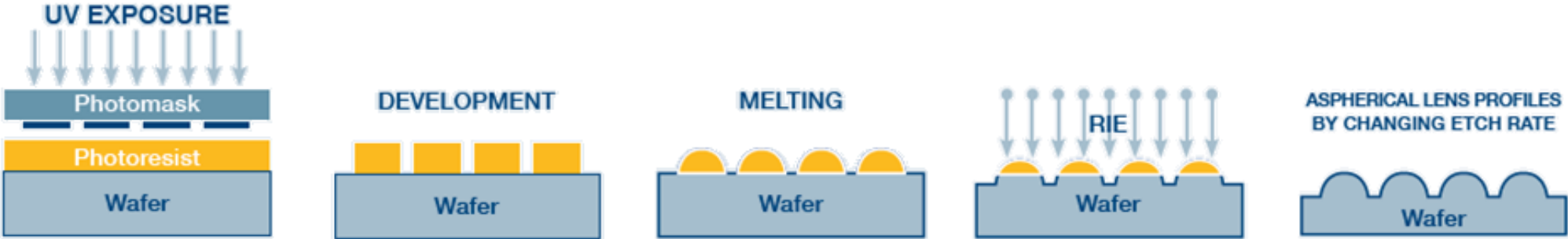
Etched Micro-Optics



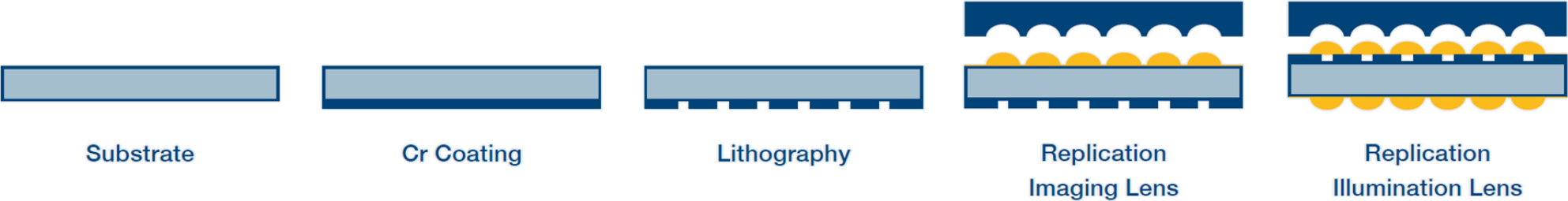
FIBER 29%



+ ETCHED – PRODUCTION OF FUSED SILICA AND SILICON OPTICAL ELEMENTS



+ IMPRINT – PRODUCTION OF POLYMER-ON-GLASS LENSES

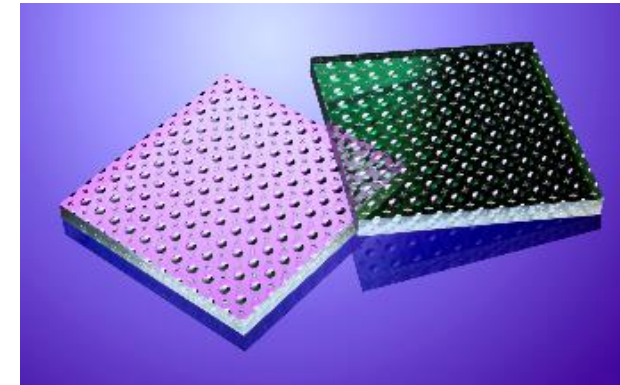


COLLIMATING MICROLENSES – SILICON OR GLASS?

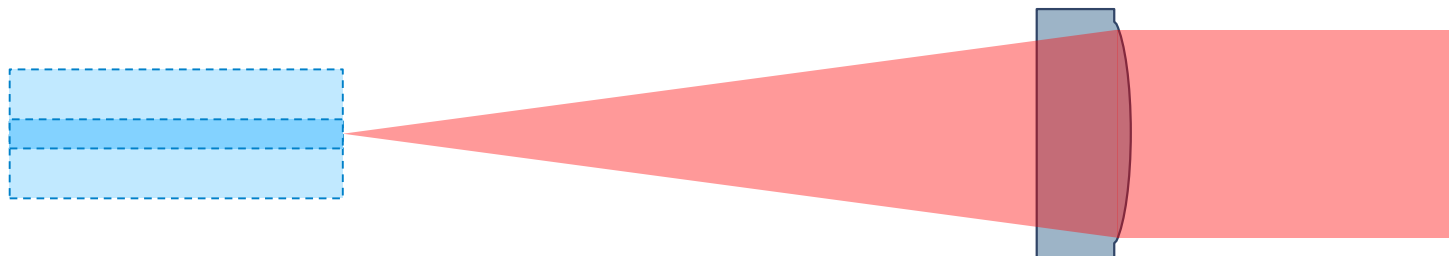
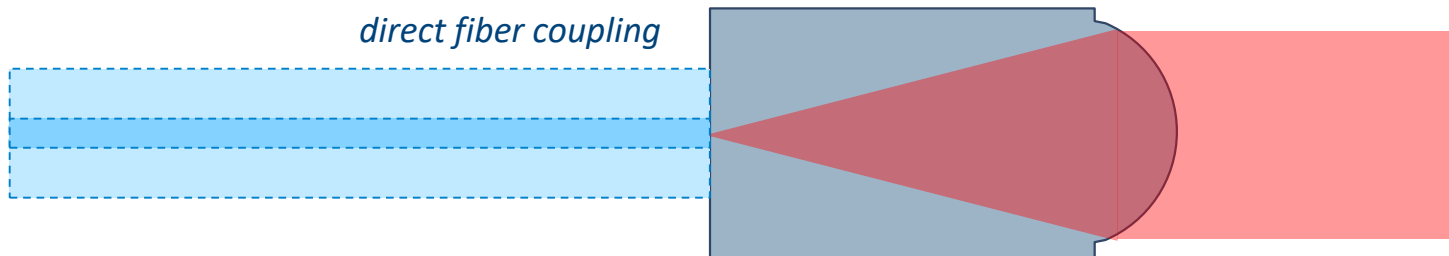
Protruding lenses - the “classic”

→ Collimation & refocusing

→ Sizes from $1 \times 1 \times 1 \text{ mm}^3$ to $100 \times 100 \times 2.25 \text{ mm}^3$



direct fiber coupling



+ Fused silica lens

- + Wafer level, high uniformity
- + Sub- μm precision
- + No dispersion, low CTE
- + Relatively thick, 1 to 3 mm
- + Combination with fiber array

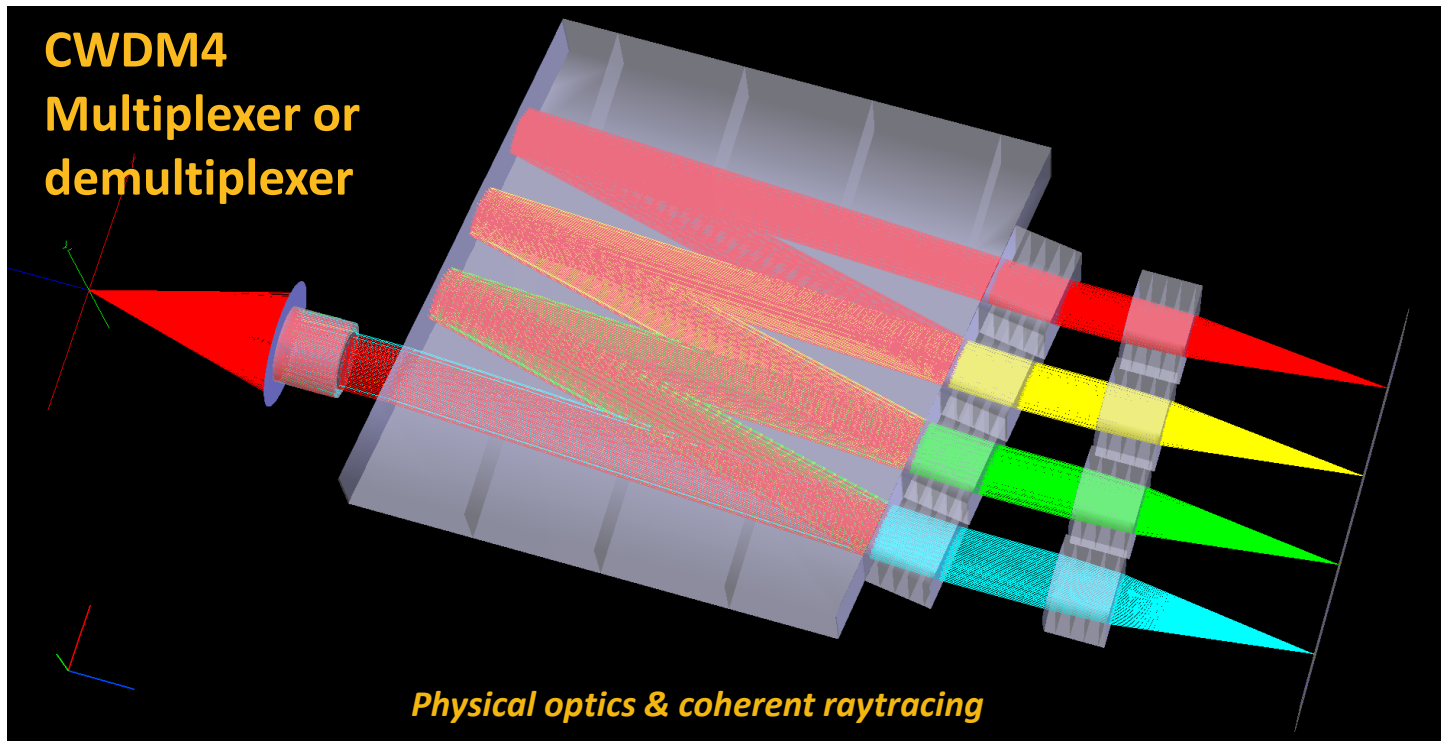
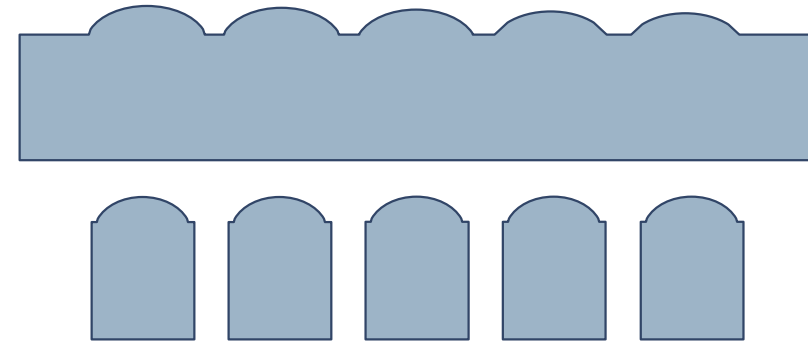
+ Silicon lens

- + Wafer level, high uniformity
- + Sub- μm precision
- + Very thin, 0.25 to 1 mm

SINGLETs OR ARRAYS FOR CWDM

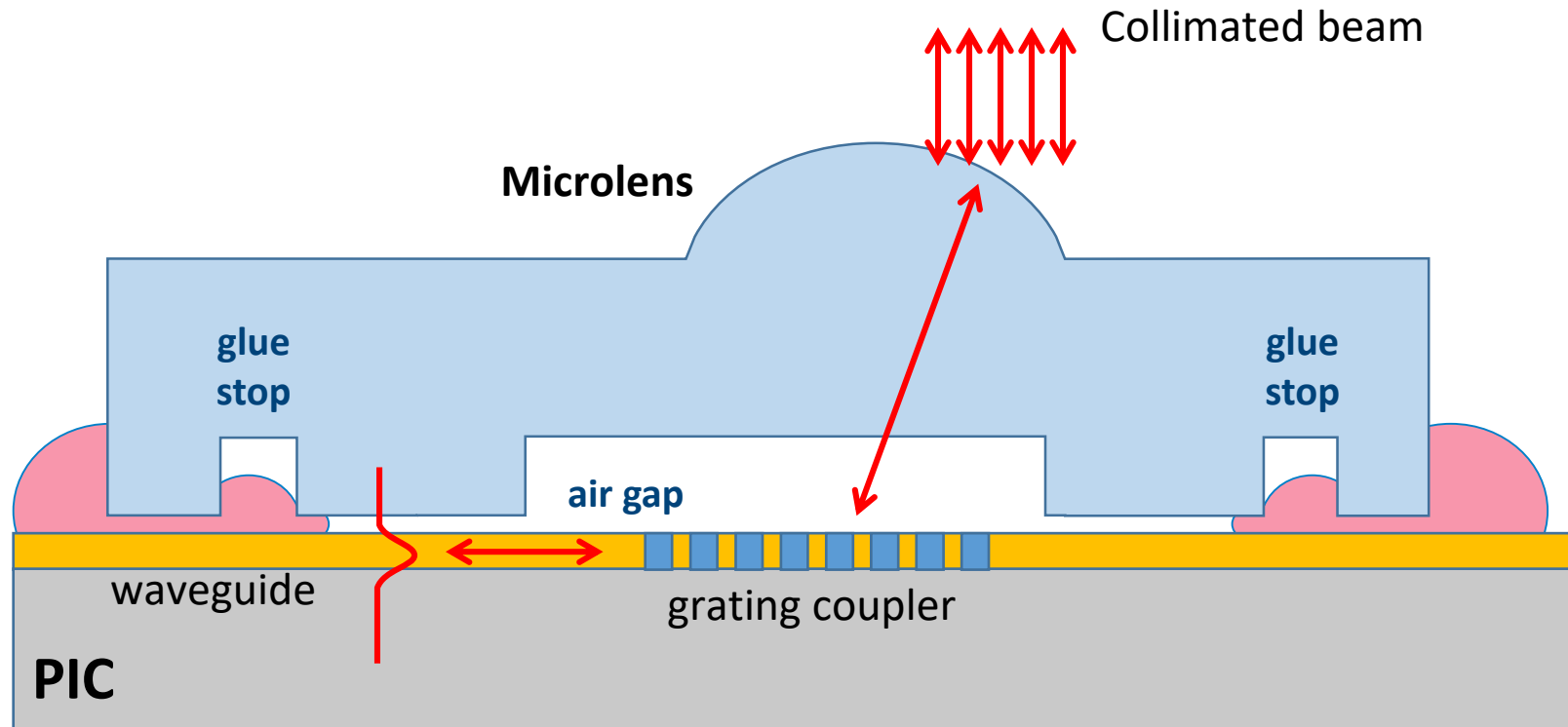
Collimating microlenses

- 1x4, 1x8 to 1xN lens arrays with perfectly aligned lenses
- Singlets <math>< 1 \times 1 \times 1 \text{ mm}^3</math>
- Collimation & refocusing
- Large lens aperture for large beam size and long distance
- Most economic options



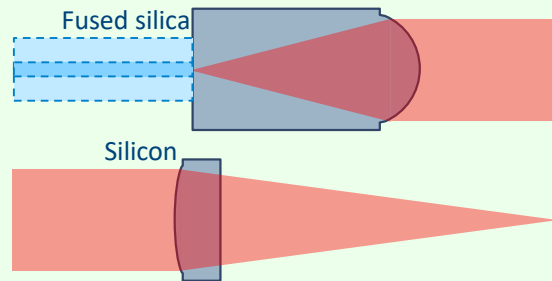
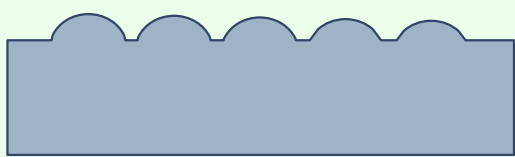
MICROLENSSES WITH PACKING FEATURES

- + Gap between PIC and grating for defined optical interface.
 - + Dust free and no adhesive at grating coupler
 - + Beam expansion
- + Small trenches as glue stops.

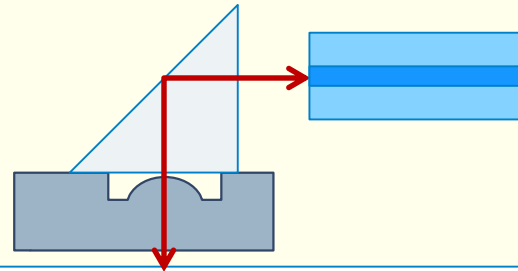
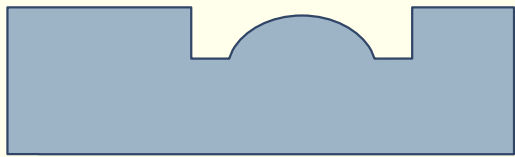


❖ Micro-Optics With Easy-Assembly Features

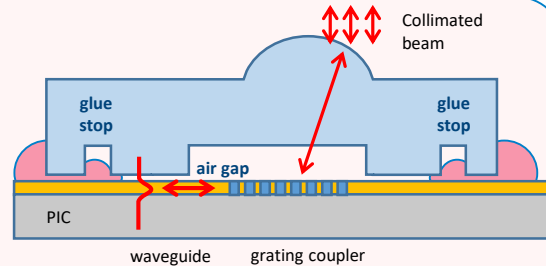
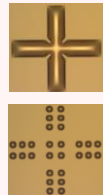
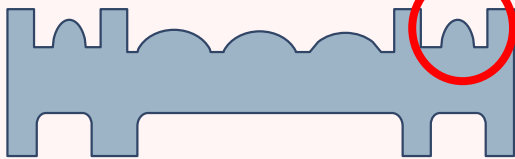
Protruding lenses for collimation



Recessed microlenses for stacking



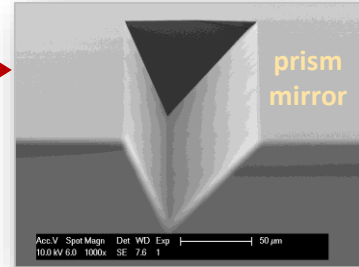
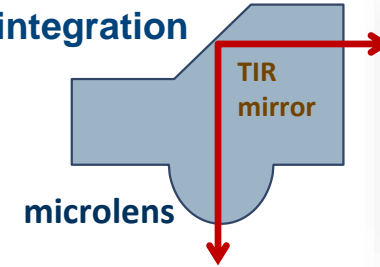
Microlenses with “adhesive management”, air gap, fiducials and trenches



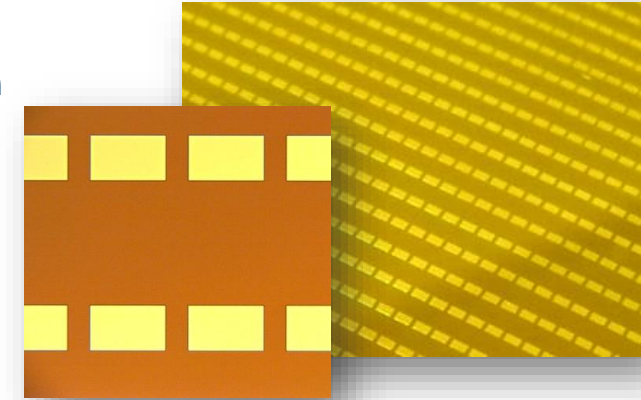
Microoptics costs lower

❖ Special Features

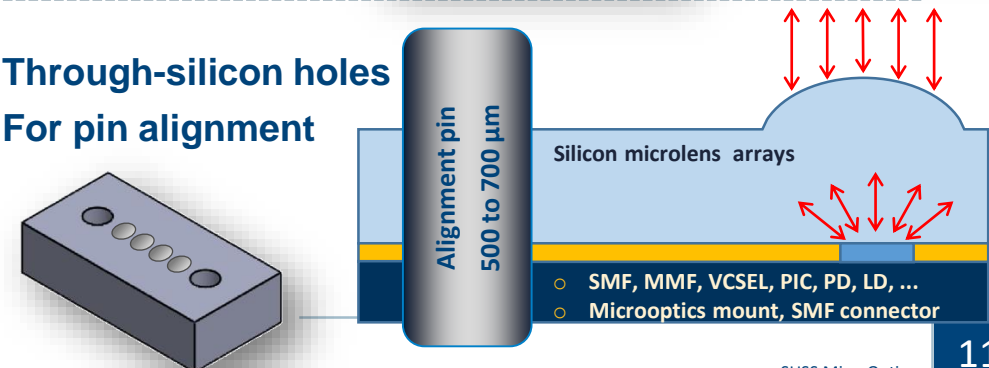
- + Integrated prisms
- + For high level integration



- + AuSn solder pads
- + Less than 3 µm thin
- + For reflow process

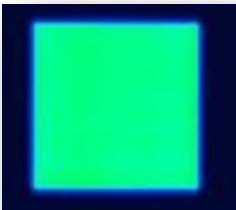
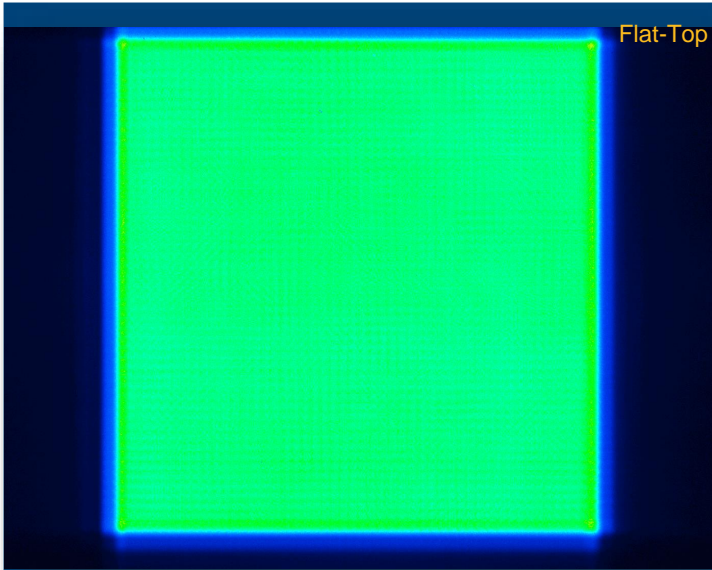


- + Through-silicon holes
- + For pin alignment

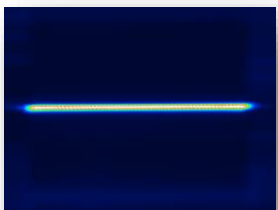


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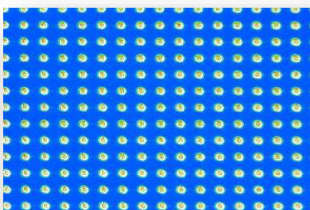
LASER BEAM SHAPING



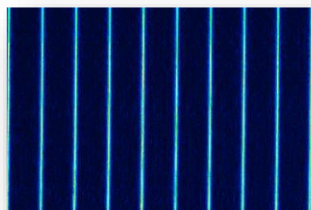
Flat-Top (2D)



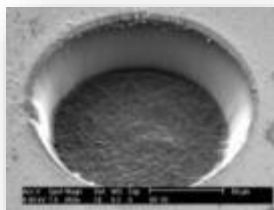
Flat-Top (1D)



Spot-Generator



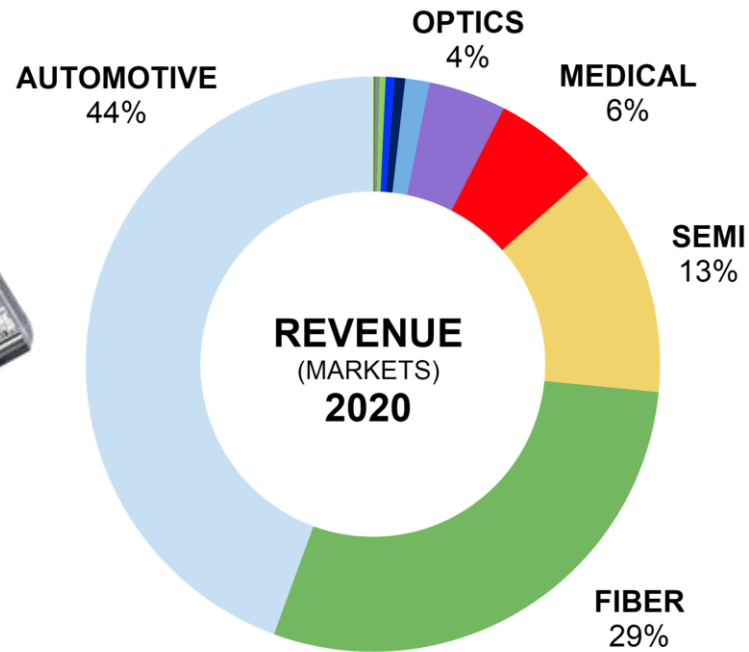
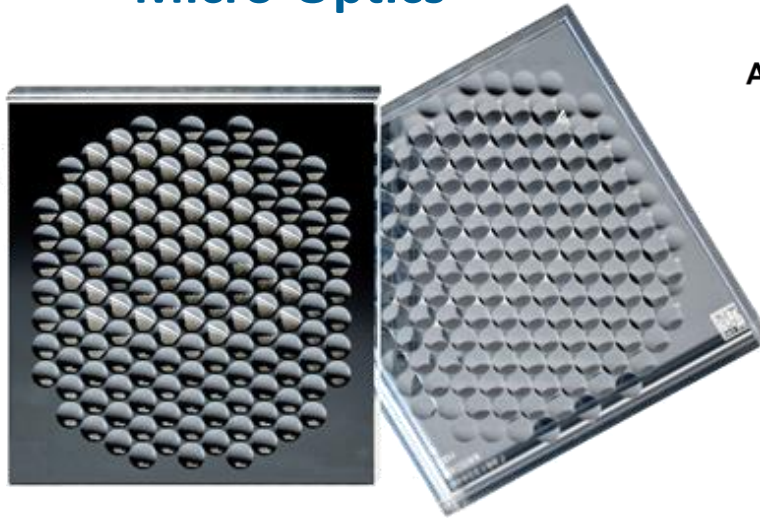
Line-Generator



Ablation

AUTOMOTIVE, ...

Imprinted Micro-Optics



Phabnoova

LIGHT CARPETS FOR DESIGN AND SAFETY

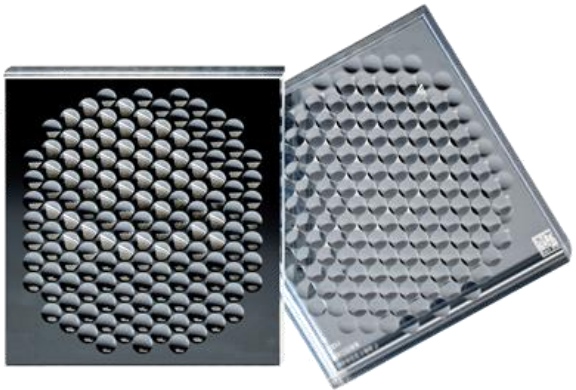
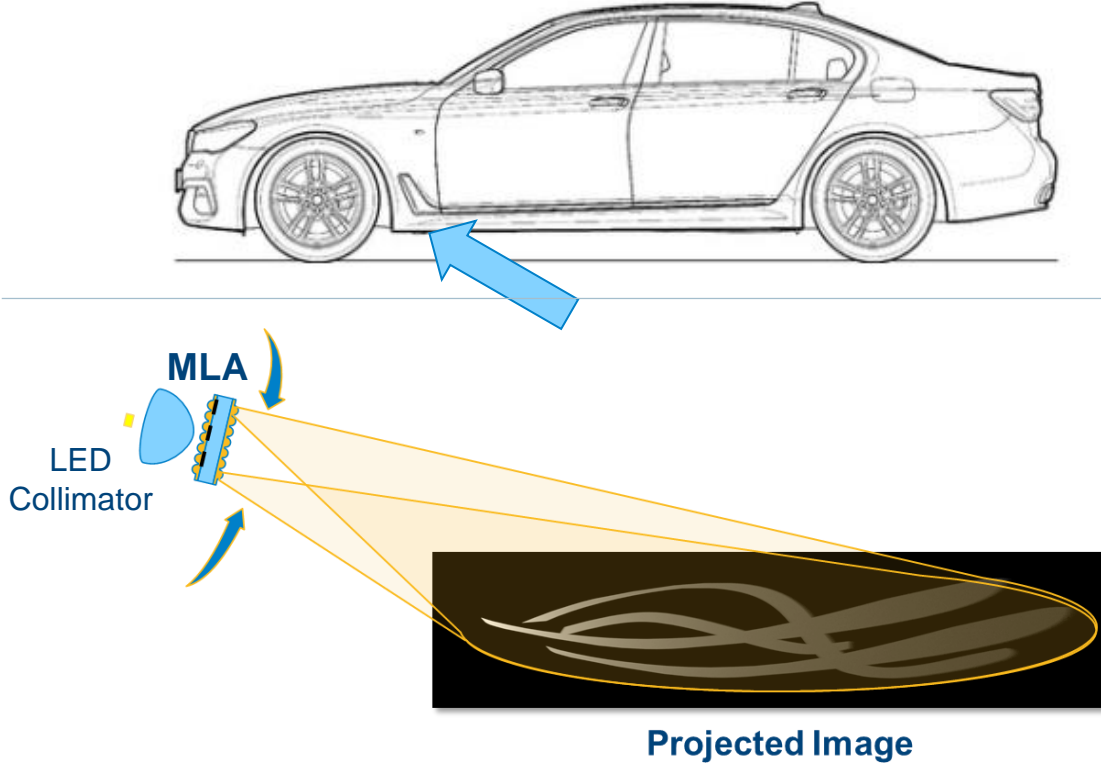
Future



Sources: BMW, www.glowwing.com

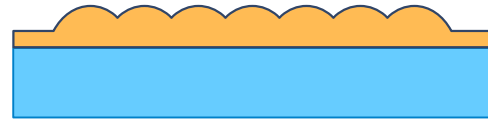
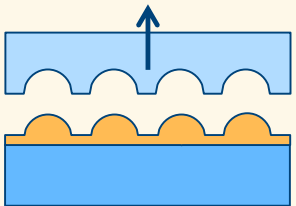
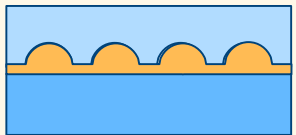
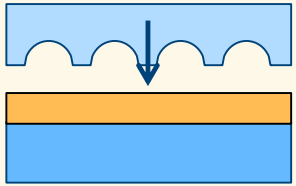
LIGHT CARPETS FOR AUTOMOTIVE

+ Development by Fraunhofer IOF (Jena), started in 2014

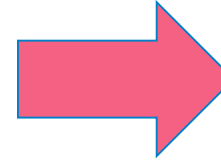


IMPRINTED MICROLENSES – WAFER-LEVEL – DOUBLE-SIDED

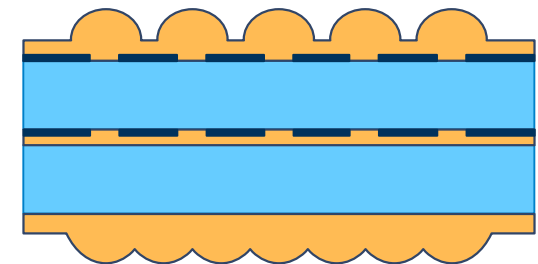
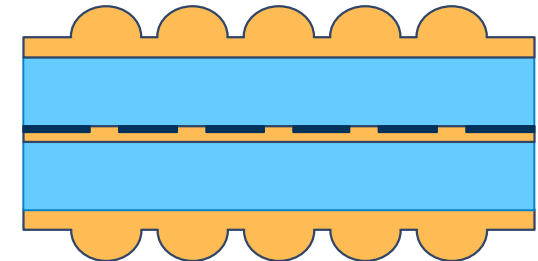
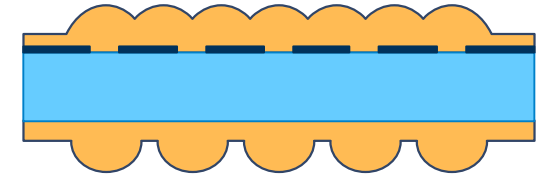
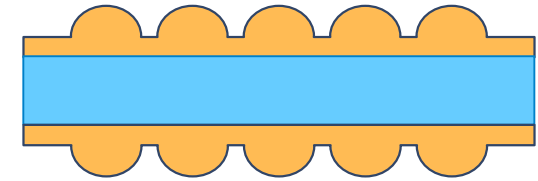
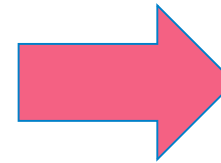
UV imprint of a liquid polymer layer on a glass substrate



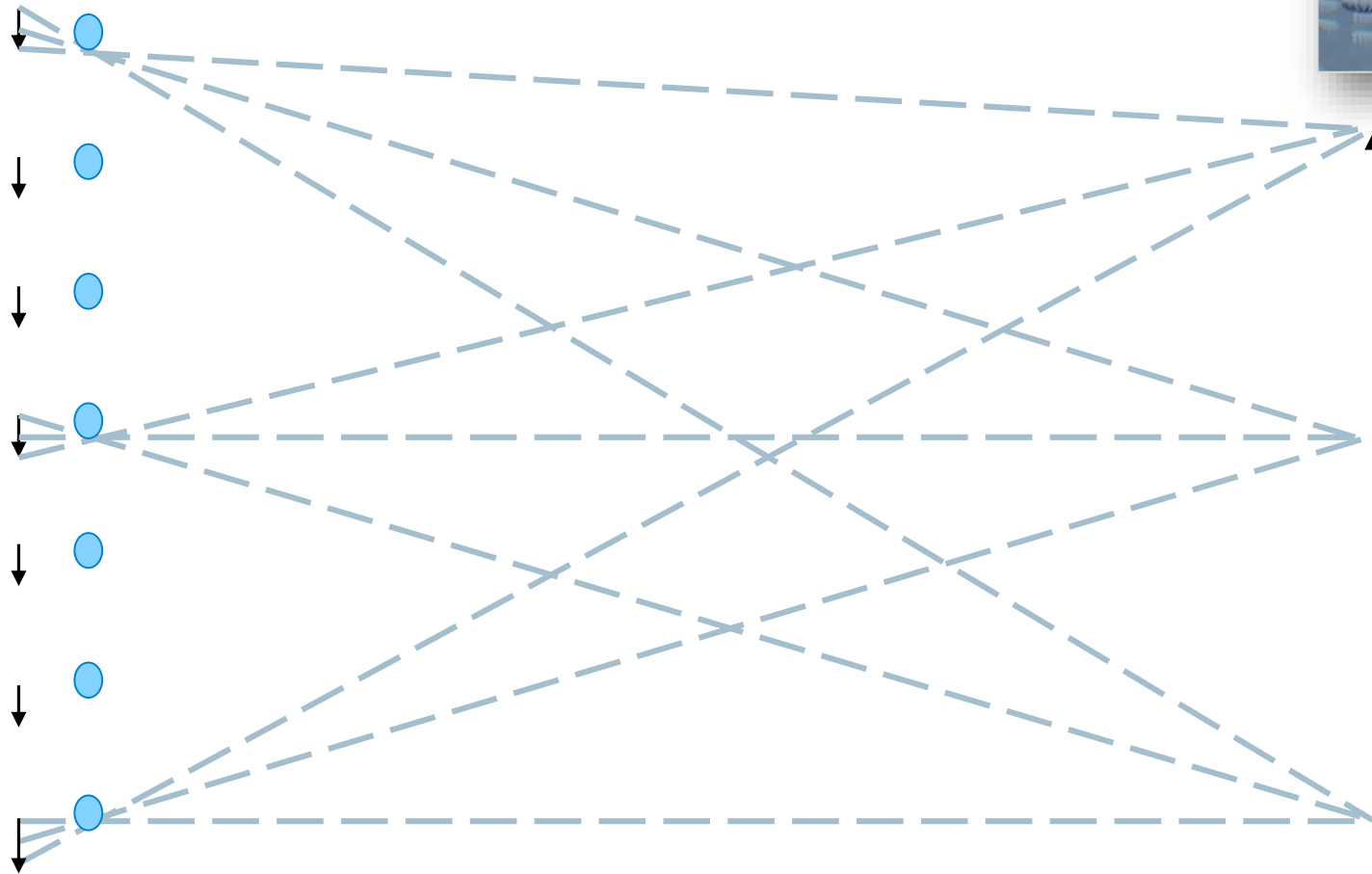
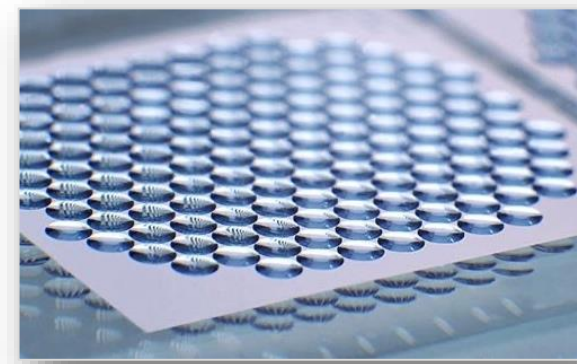
Front- and Backside Optics



- ❖ Double-sided MLAs
- ❖ Precisely aligned
- ❖ Embedded apertures

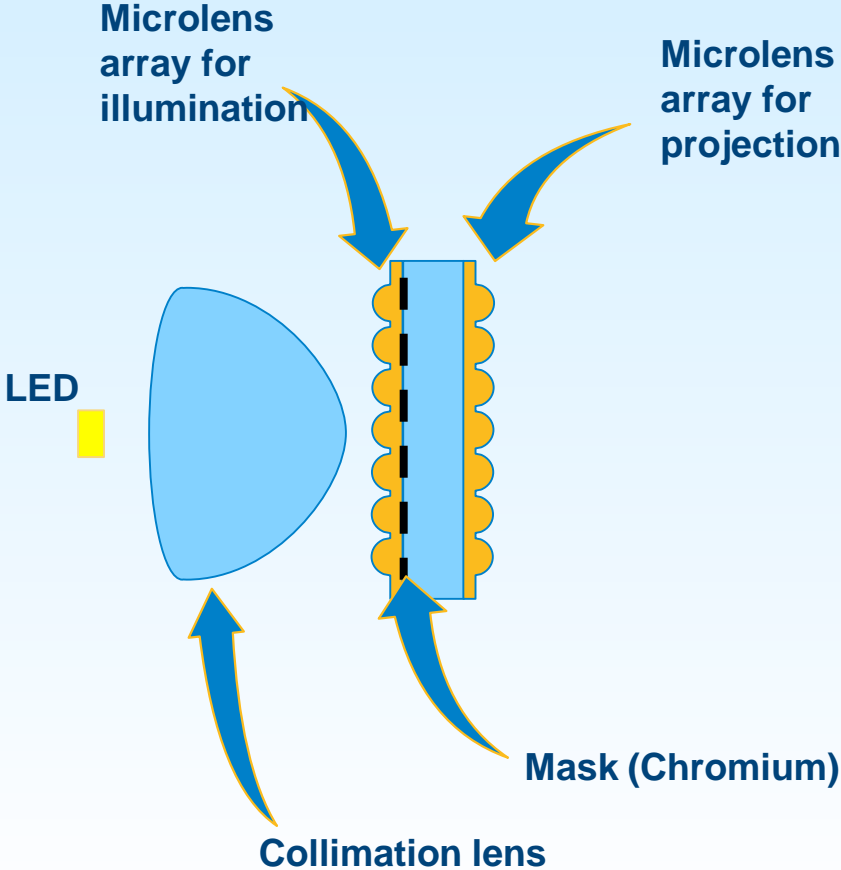


MICRO LENS ARRAY (MLA)

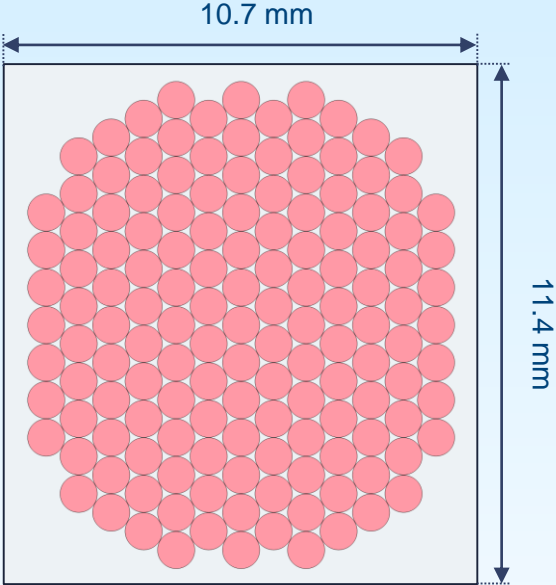


- + Design of Chromium Apertures
- + Superposition leads to bright integral image
- + Areas of sharpness depends on location of chromium masks

Concept

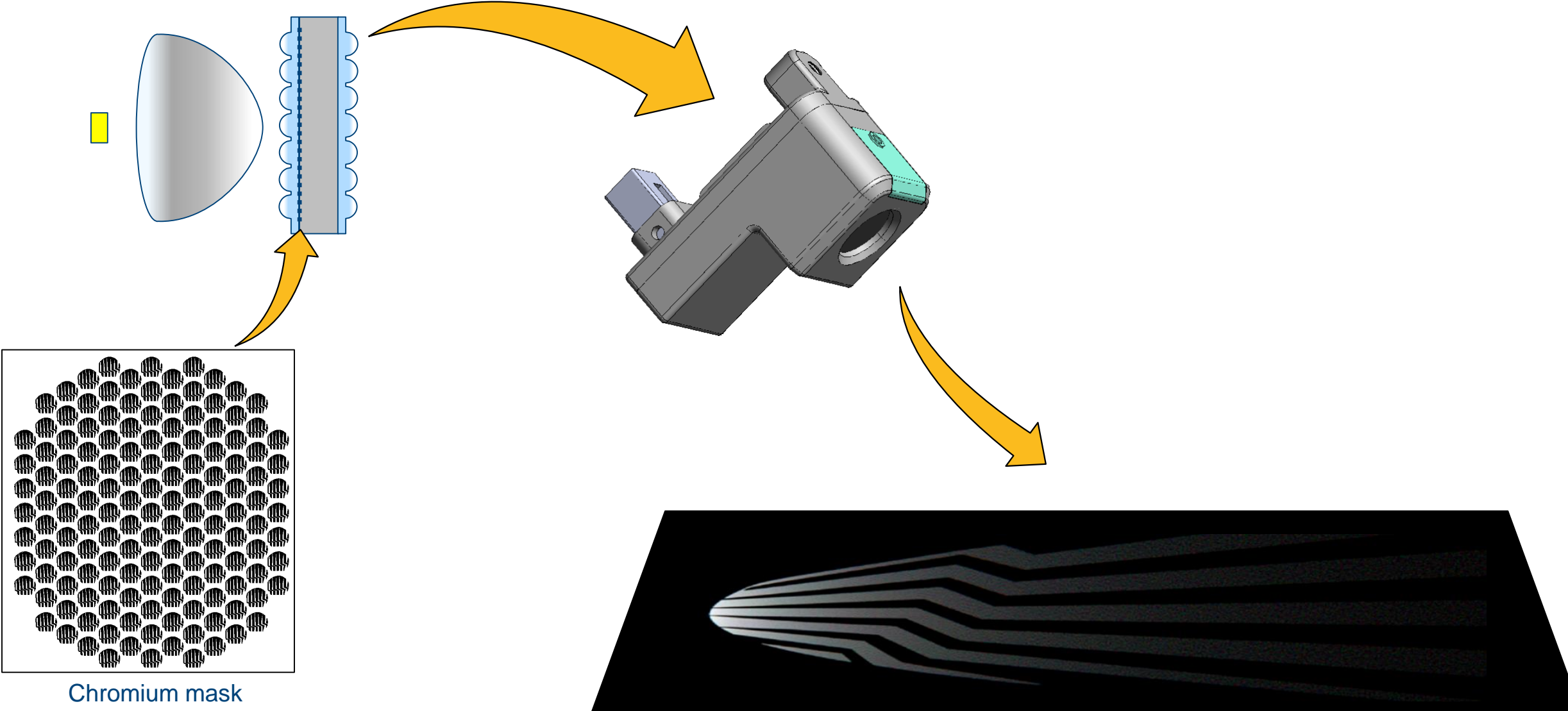


Geometry



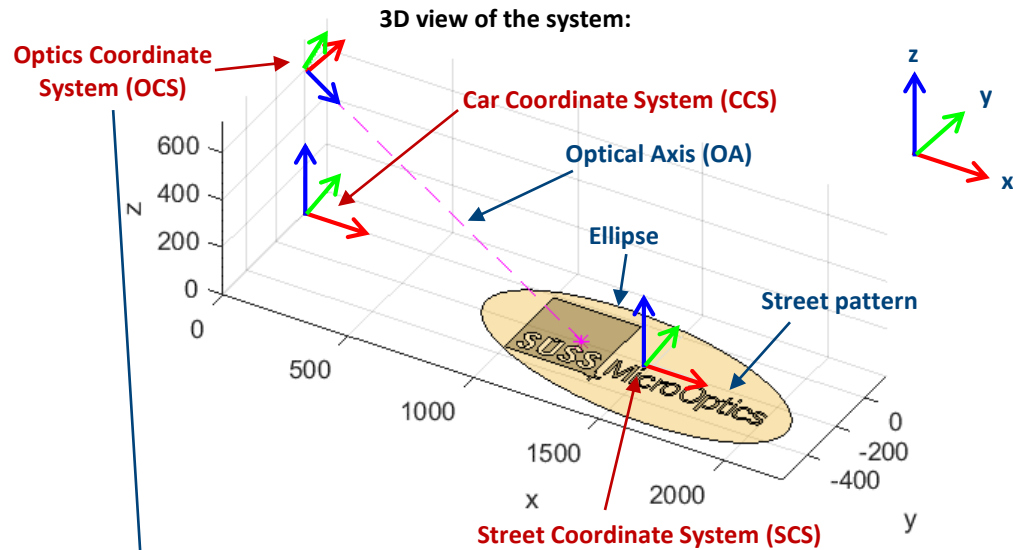
Microlens diameter: 800 μm

LIGHT CARPET SETUP



Chromium mask

GEOMETRIC RELATIONS

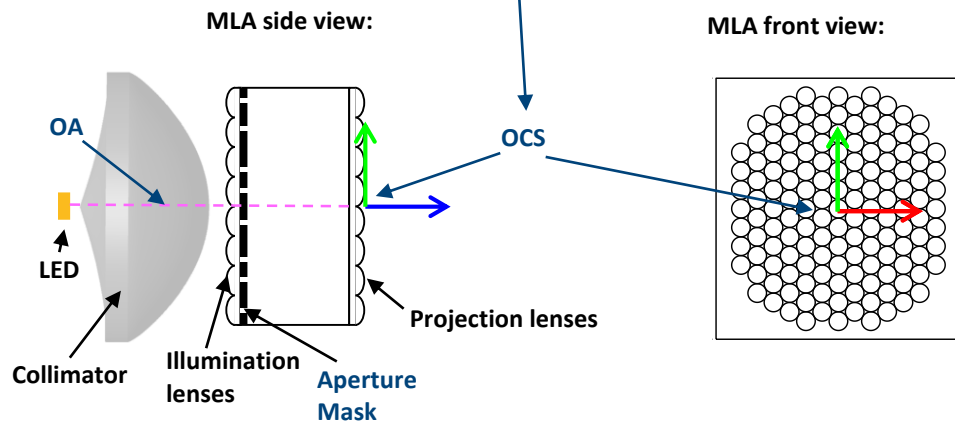


	X-center	Y-center	Z-center	Tilt about X	Tilt about Y	Tilt about Z
CCS	0 mm	0 mm	0 mm	0°	0°	0°
OCS	0 mm	600 mm	0 mm	152.826°	6.234°	-176.809°
SCS	200 mm	0 mm	-1300 mm	-90°	0°	-90°



Geometrical description compatible with Zemax notation!

Object Type	Comment	Ref Object	Inside Of	X Position	Y Position	Z Position	Tilt About X	Tilt About Y	Tilt About Z
1	Null Object ▾ CCS: Car Coordinates Origin	0	0	0.000	0.000	0.000	0.000	0.000	0.000
2	Null Object ▾ OCS: Optics Coordinates Origin	1	0	0.000	600.000	0.000	152.826	6.234	-176.809
3	Null Object ▾ SCS: Street Coordinate Origin	1	0	200.000	0.000	-1300.000	-90.000	0.000	-90.000



PROCESS FLOW – MASK GENERATION

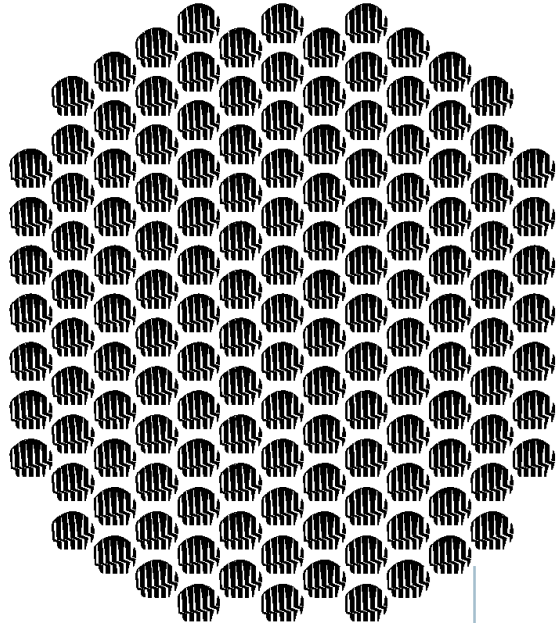
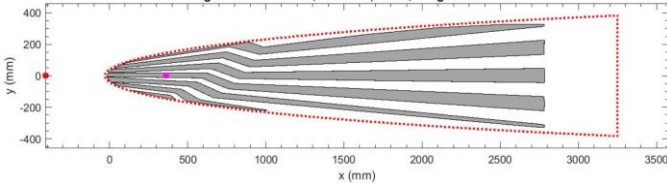
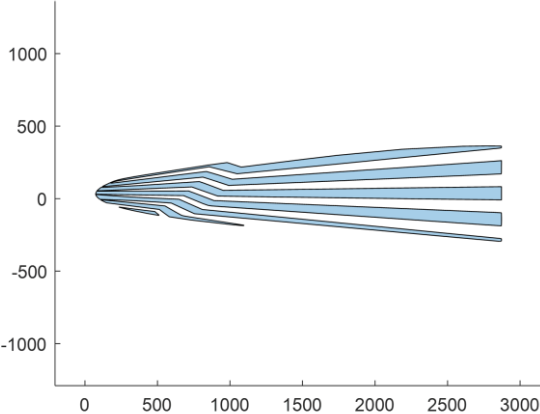
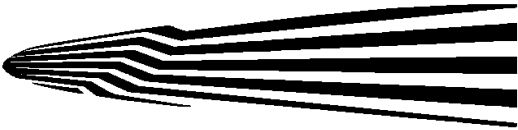
Iterations with the customer to reach a manufacturable design

Target configuration and pattern from customer

Convert to format which can be processed

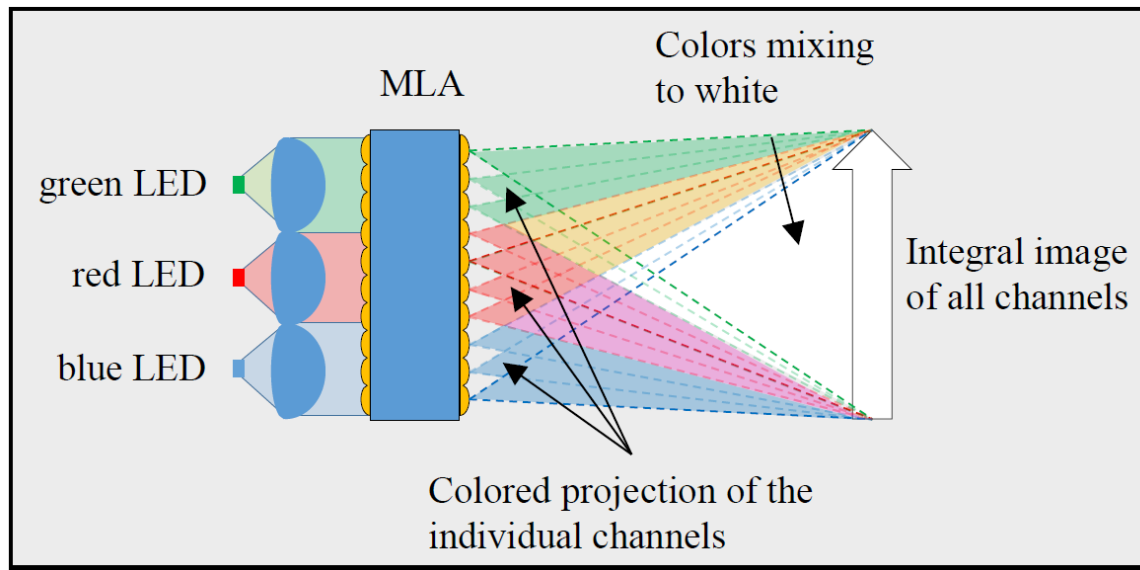
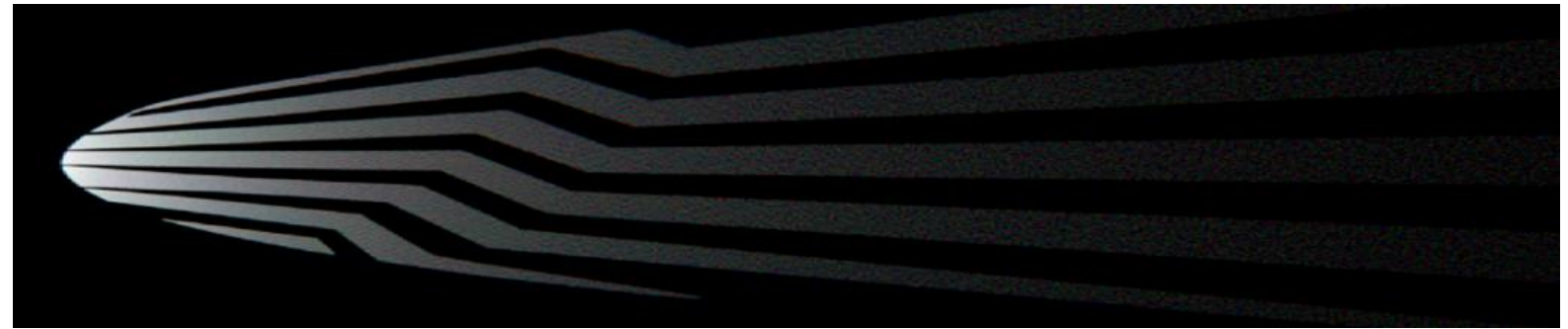
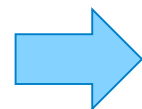
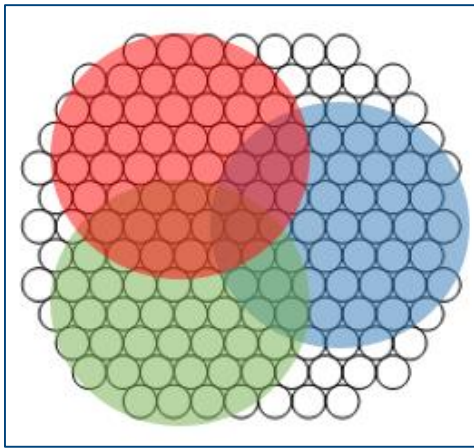
Check for geometry and FOV

Mask generation

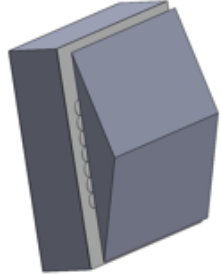
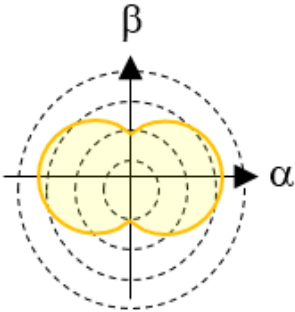
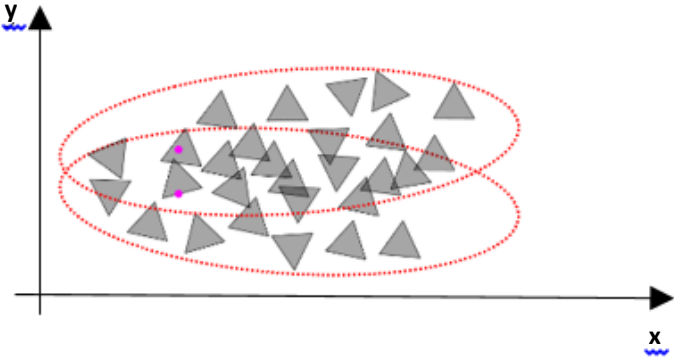


COLOR MIXING WITH MICROLENS ARRAY (MLA)

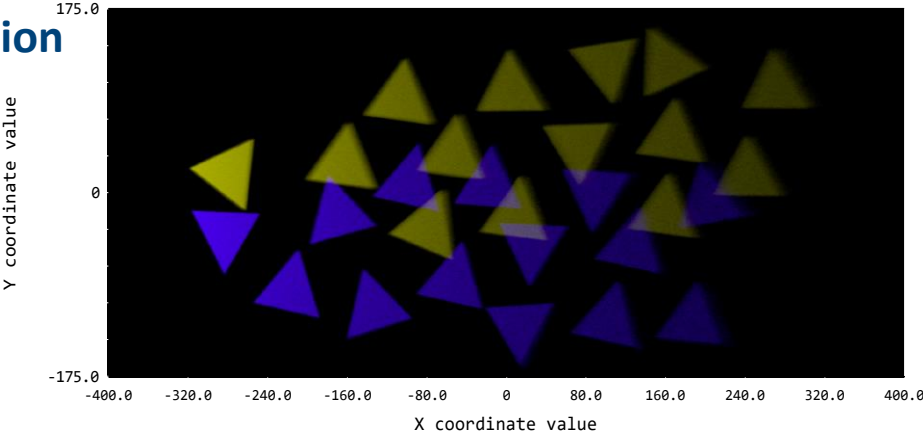
+ Integrated light mixing for RGB projections



NEXT GEN? MLA WITH PRISMS!

MLA + prism	FOV in angle space	Pattern and FOV (dashed line) on the target surface
		

Simulation

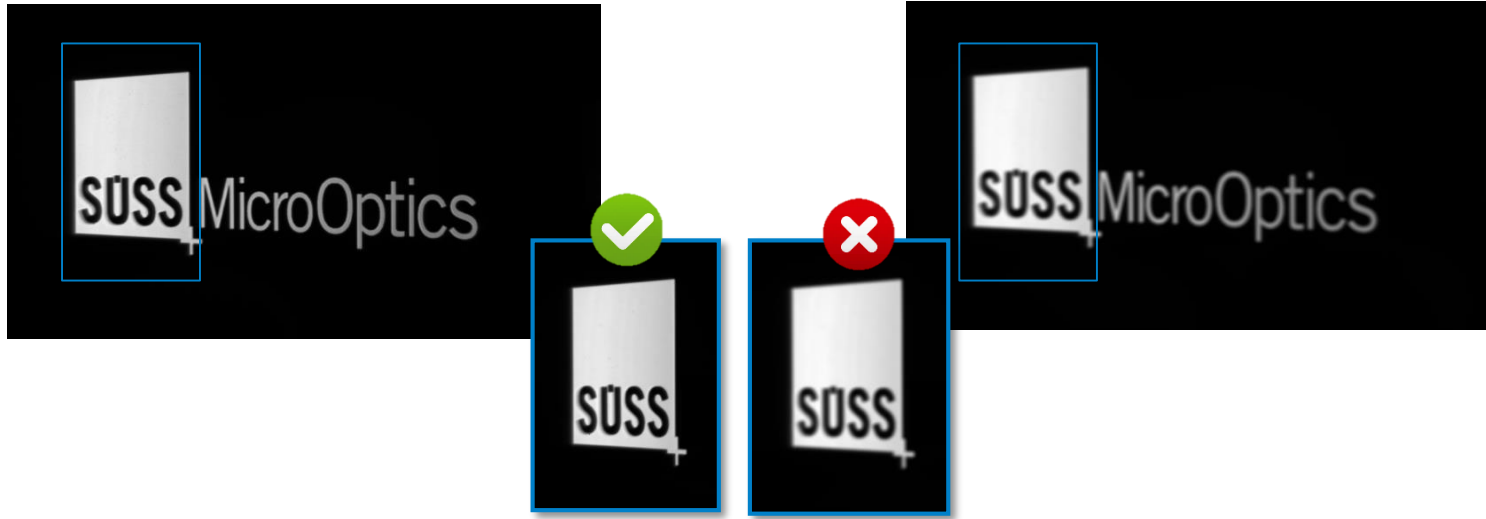


Application Parking assistant

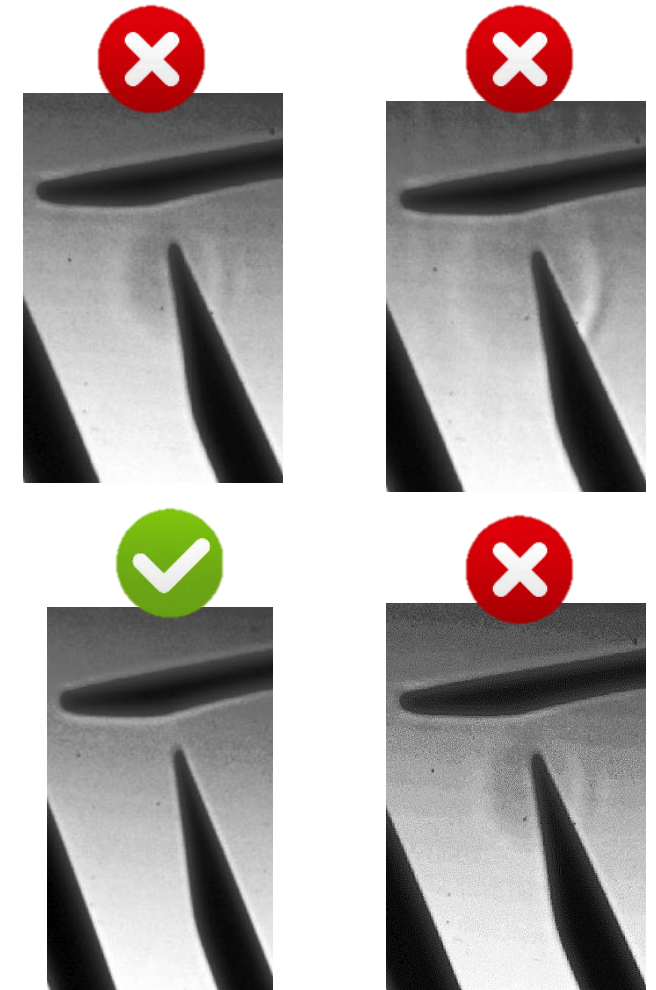


MACHINE LEARNING FOR PATTERN RECOGNITION

Sharpness



Local Defects



Background Uniformity



MICROLENS - ULTRA-SLIM HEADLIGHTS

- + Why do people buy new cars?
 - Innovative features, technology
 - Design, beauty and uniqueness
- + 1st microlens headlamps in cars in 2021
- + Ultra-slim headlamps are the new trend



Lucid Motors, Hyundai

MICRO-OPTICS HEADLIGHTS



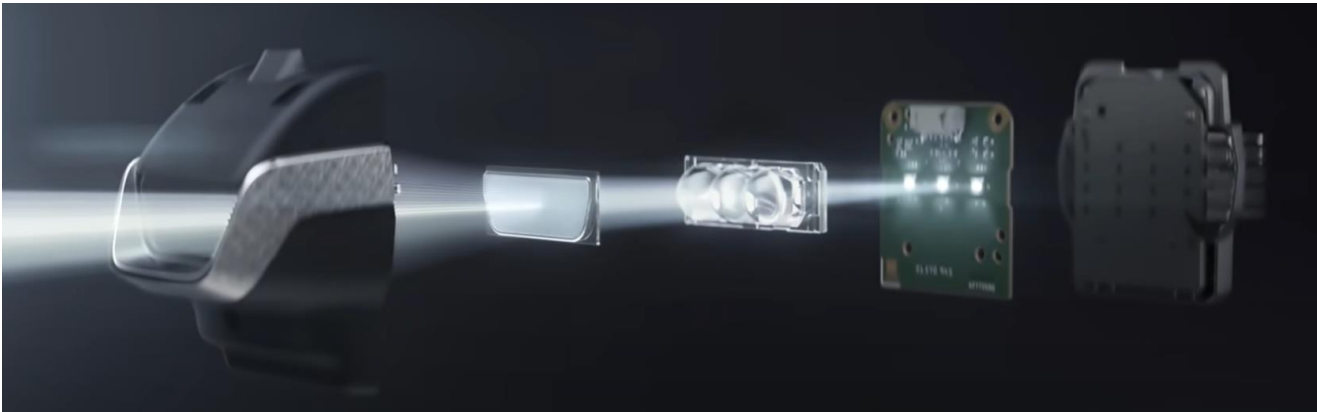
Lucid Air, top view



Headlight



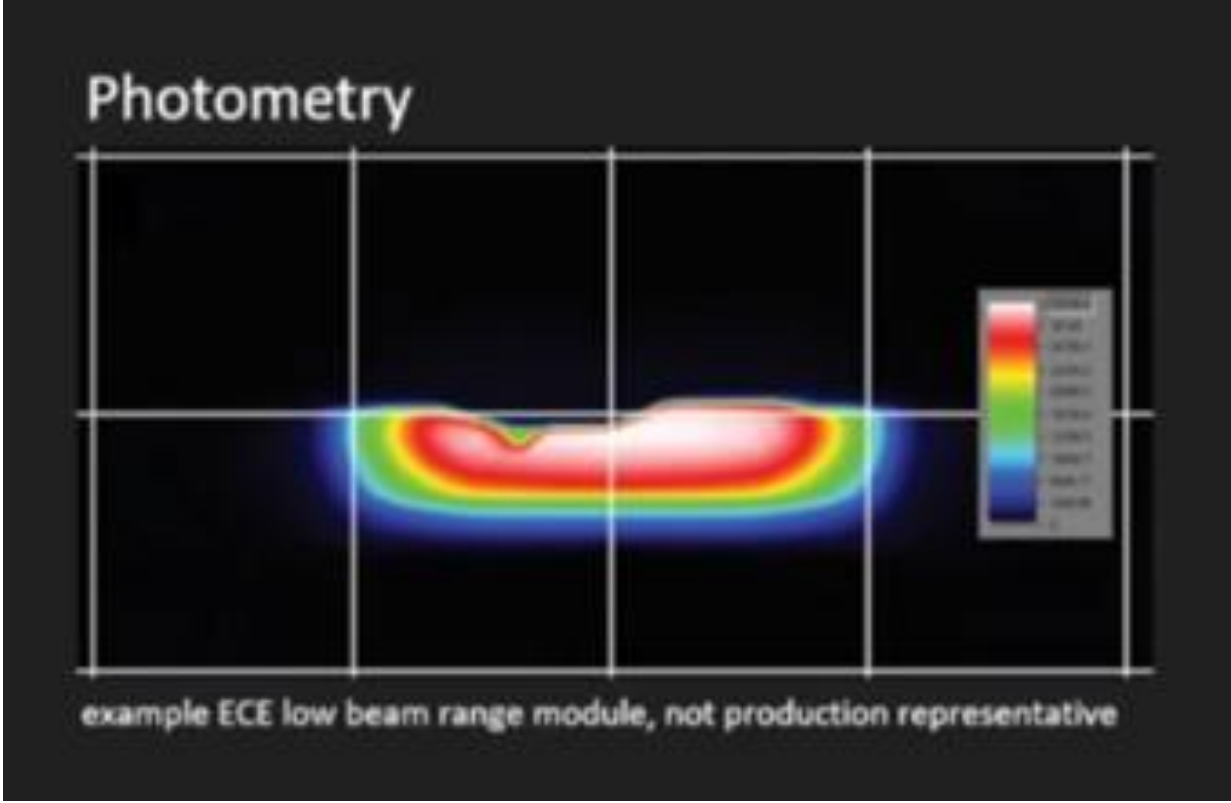
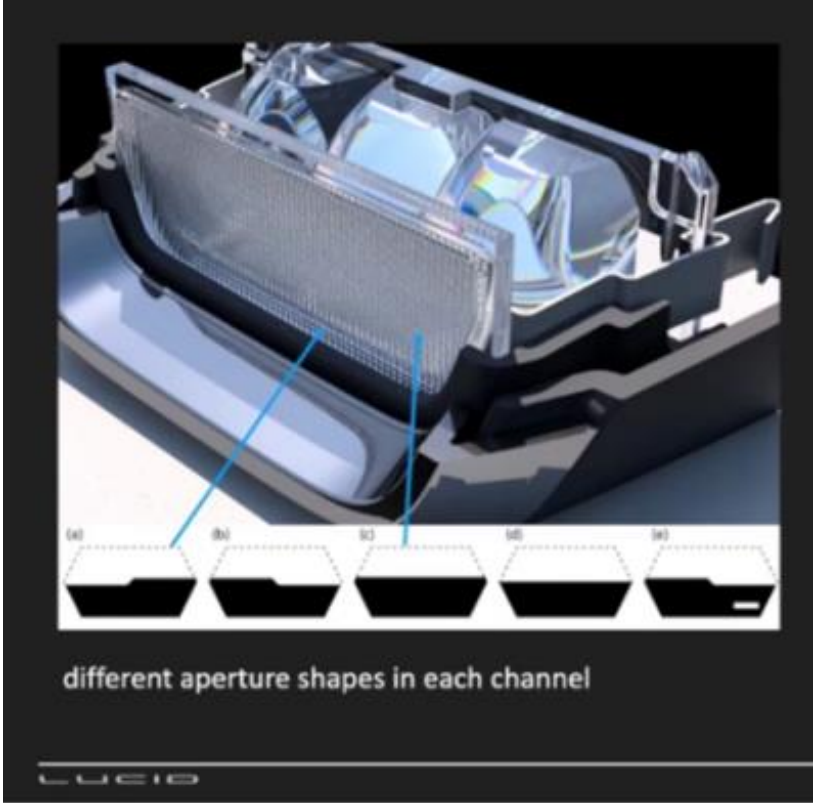
Module



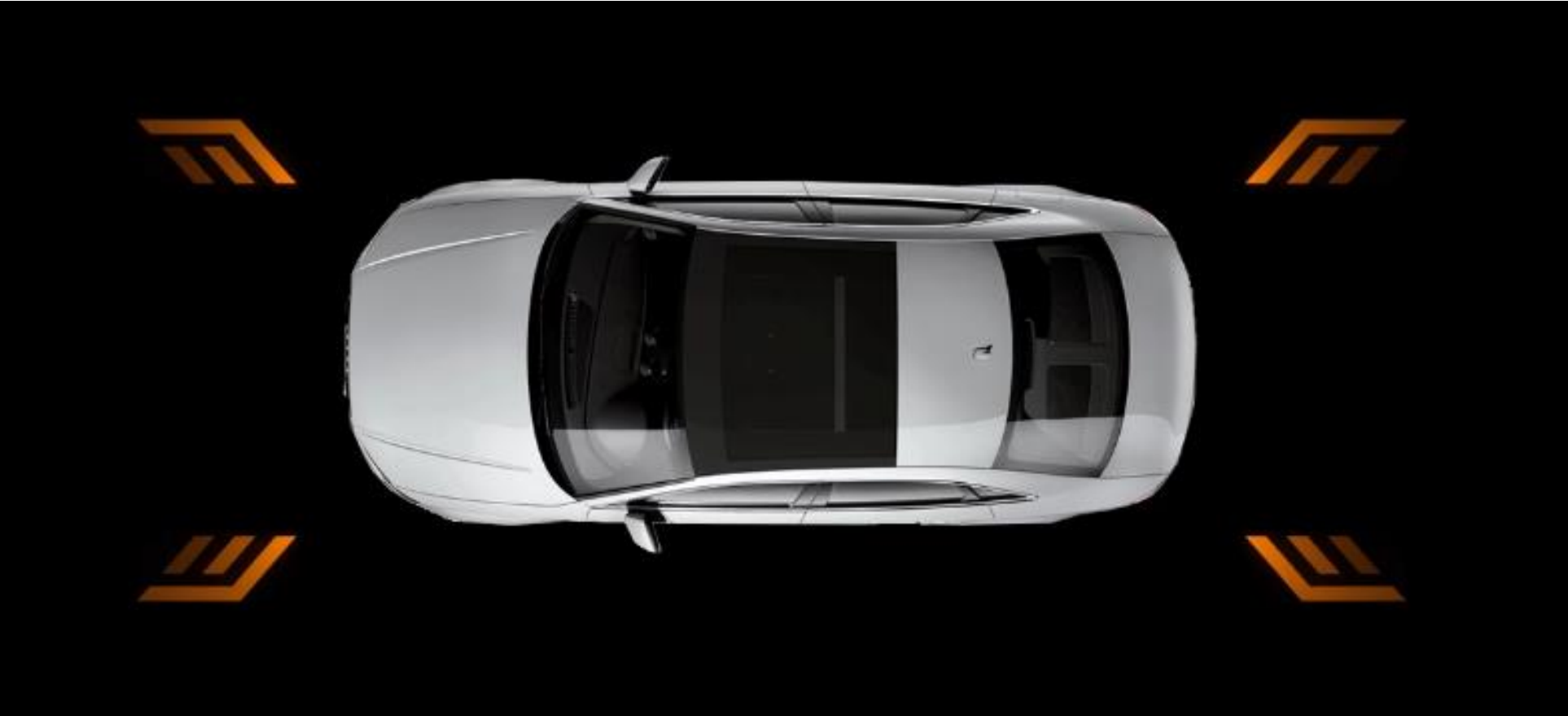
Module, exploded view

Lucid Motors

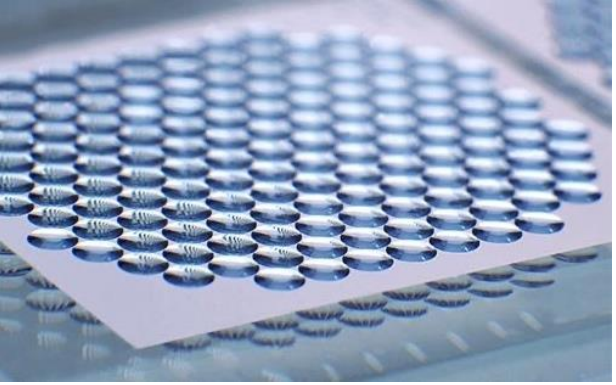
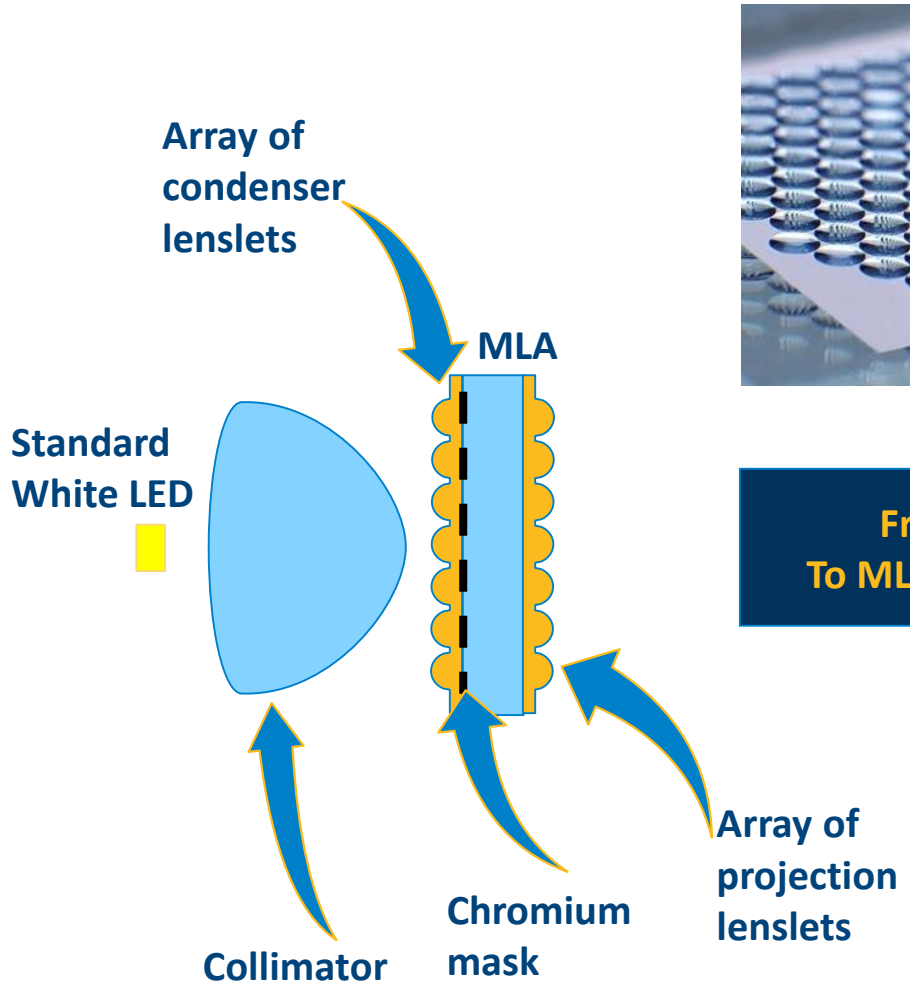
MICRO-OPTICS LIGHT SHAPING



THE NEXT BIG THING: SAFETY WITH LIGHT

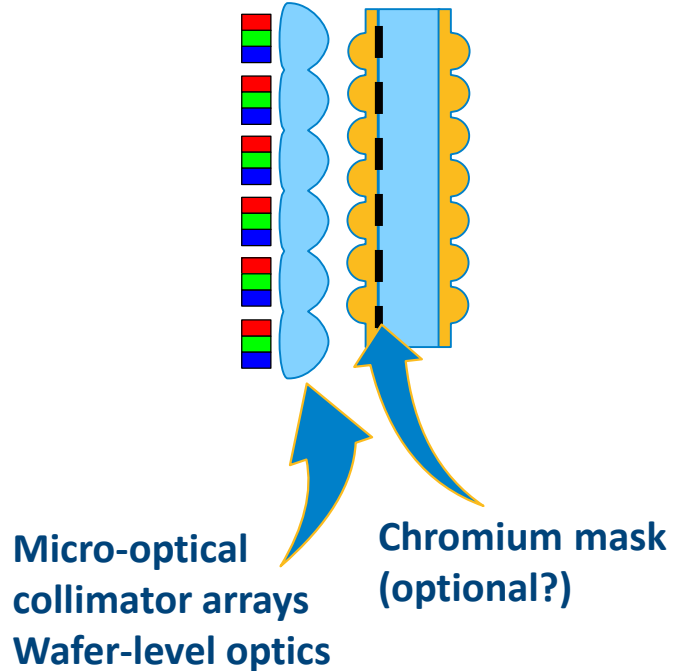


HOW MICRO-OPTICS CAN HELP MICROLEDS



From "classical" MLA
To MLA-enhanced MicroLEDs

MicroLED Array with integrated microoptics

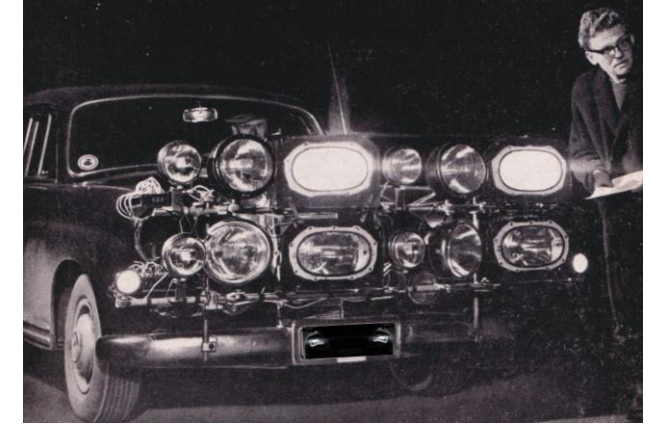


The Opportunity

- + Headlamps integrated and hidden in the design
- + Not many concepts out there for miniaturization
- + Micro-Optics is by far the most-promising approach for the next generations of automotive lighting solutions.

Challenges and Key Developments

- + Design flexibility
 - Size, weight and power consumption
- + Higher efficiency
 - Lower energy consumption (EV)
- + Visible innovation and uniqueness
 - Premium cars, individualization
- + Cost reduction



BMW Laser Light (ZKW)



Lucid Air – Microlens Head Lights

Thank you!



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