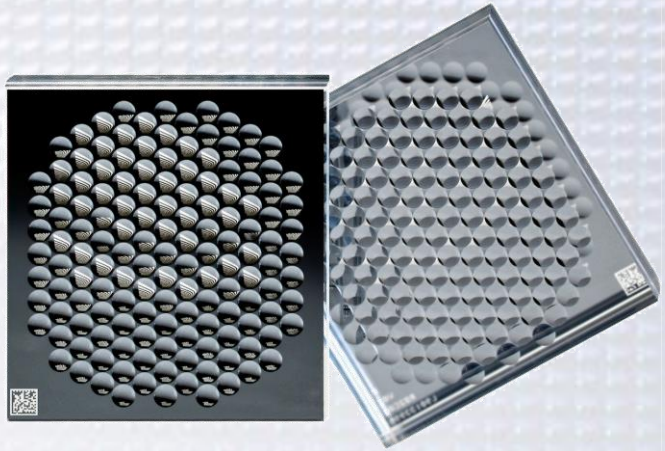
MULTICHANNEL MICRO-OPTICS FOR COMPACT AUTOMOTIVE LIGHTING SOLUTIONS

Giorgio Quaranta, PhD – Senior Optical Designer and Project Manager



SUSS MICROOPTICS SA

20 Years of Micro-Optics FAB Experience

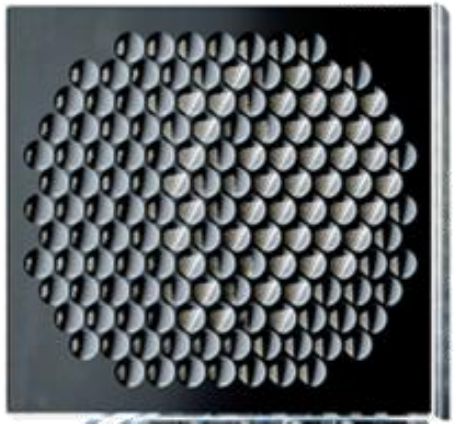
SÜSS MicroOptics

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

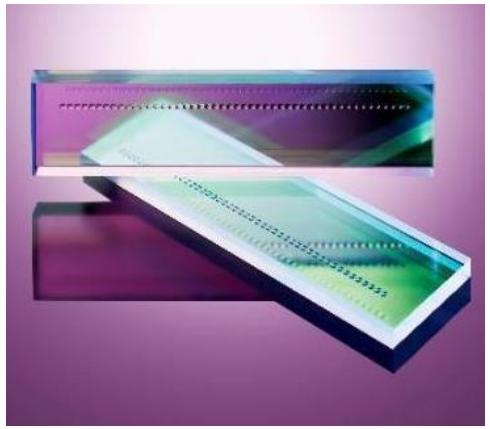
- Founded 1998
- Refractive microoptics
- Diffractive microoptics
- Worldwide client base in data/telecom, metrology, semiconductor, instruments
- Part of the SUSS MicroTec Group

PRODUCTS AND MARKETS

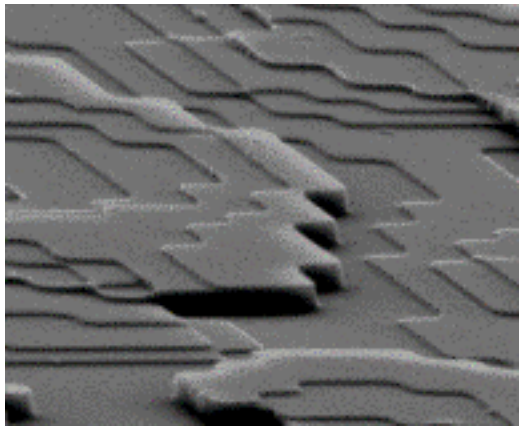
+ AUTOMOTIVE



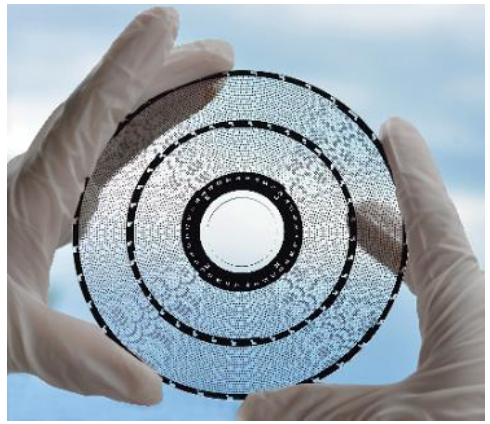
+ TELE/DATACOM



+ SEMICONDUCTOR



+ MEDICAL



AUTOMOTIVE INDUSTRY – OPPORTUNITIES FOR MICRO OPTICS

SÜSS MicroOptics

The Opportunity

- Lighting modules 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.

BMW – Daytime Running Light (DRL)
Microprism Arrays

BMW – Light Carpet
Microlens Arrays

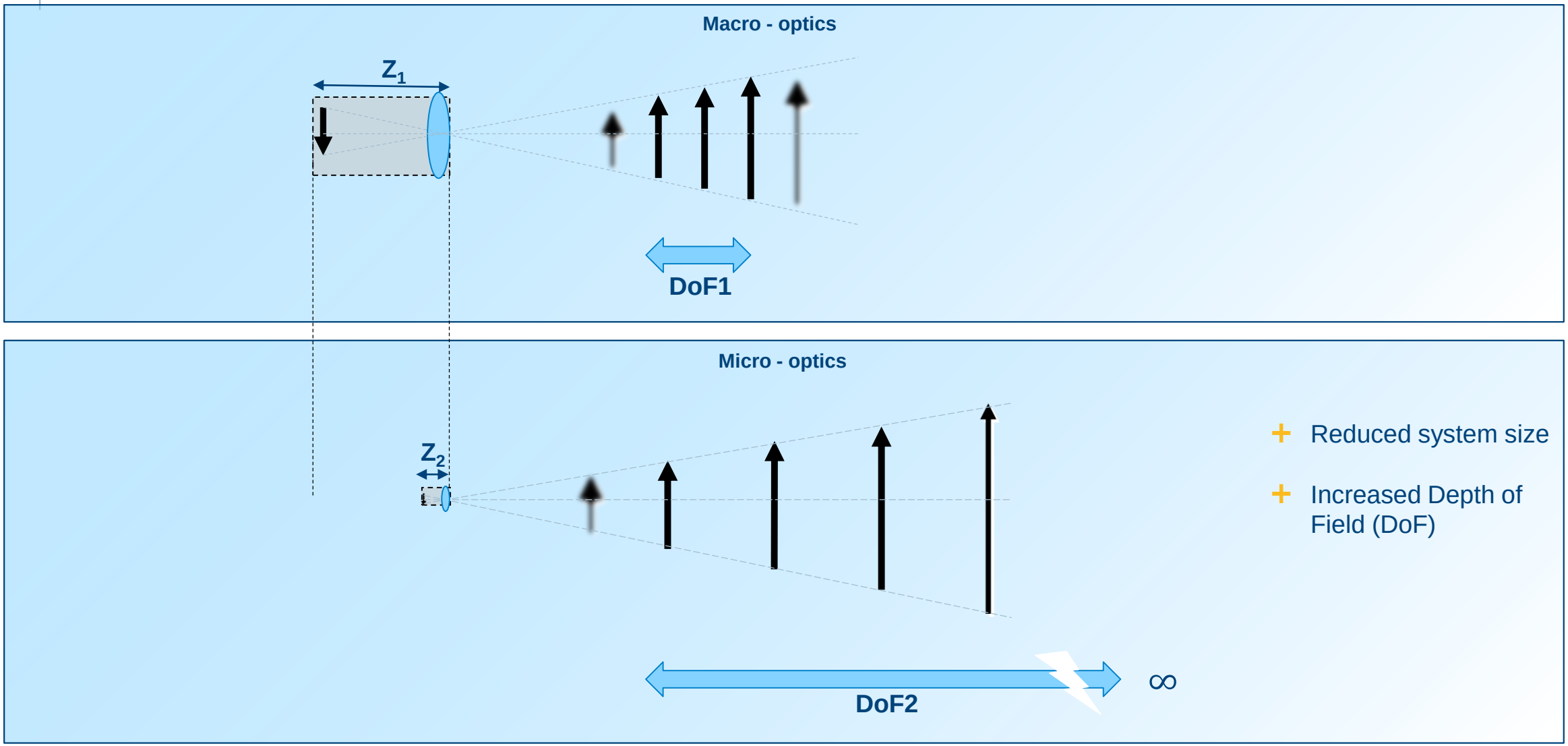
Challenges and Key Developments

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

Hella – Rear Light
Diffractive Microstructures

Lucid Air – Head Lights
Microlens Arrays

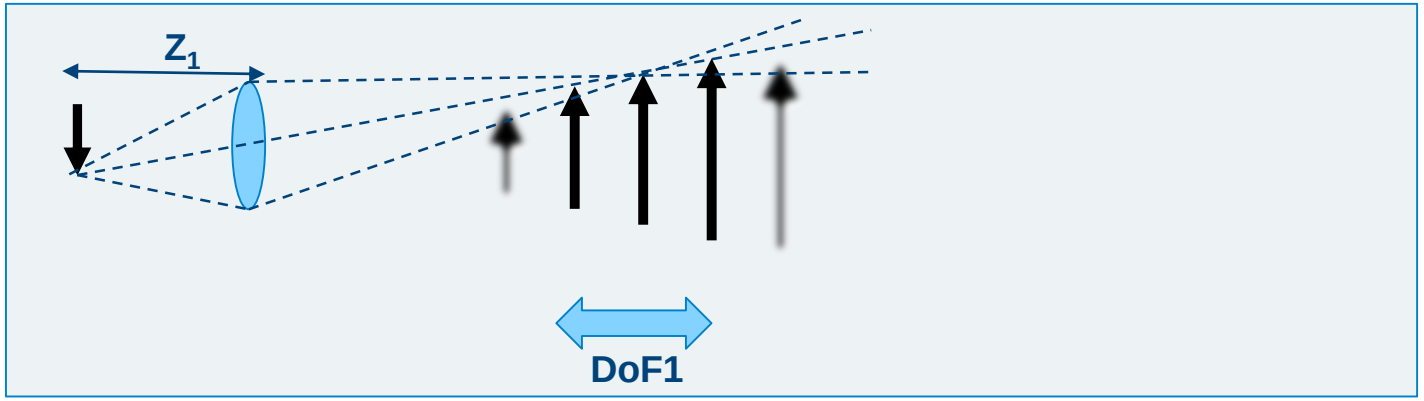
MACRO VS MICRO OPTICS



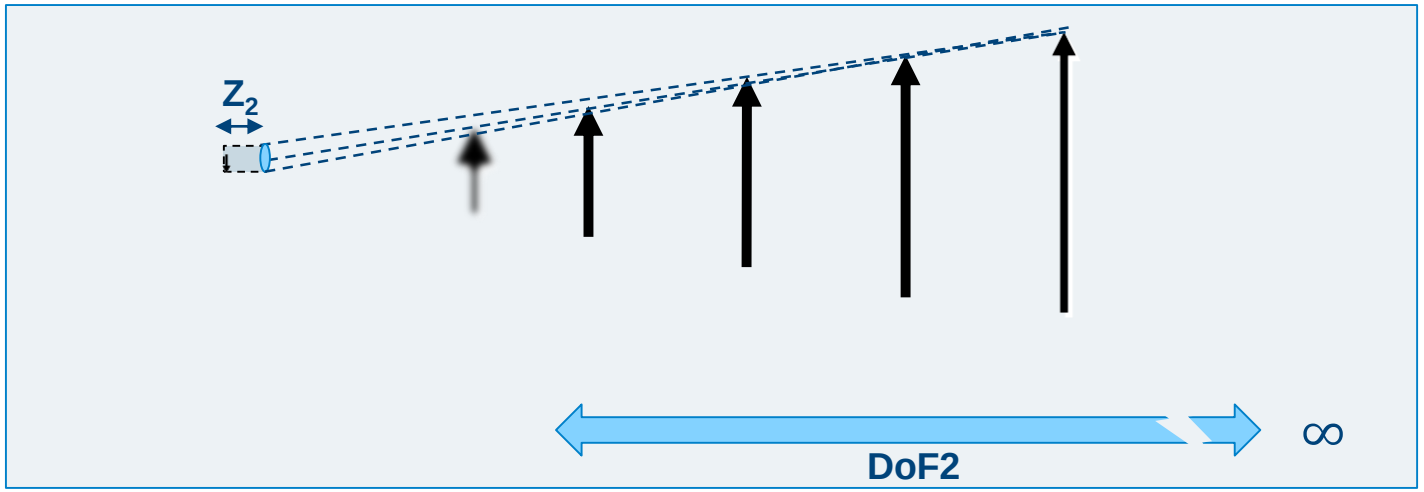
+ Reduced system size
+ Increased Depth of Field (DoF)

MACRO VS MICRO OPTICS

Macro - optics

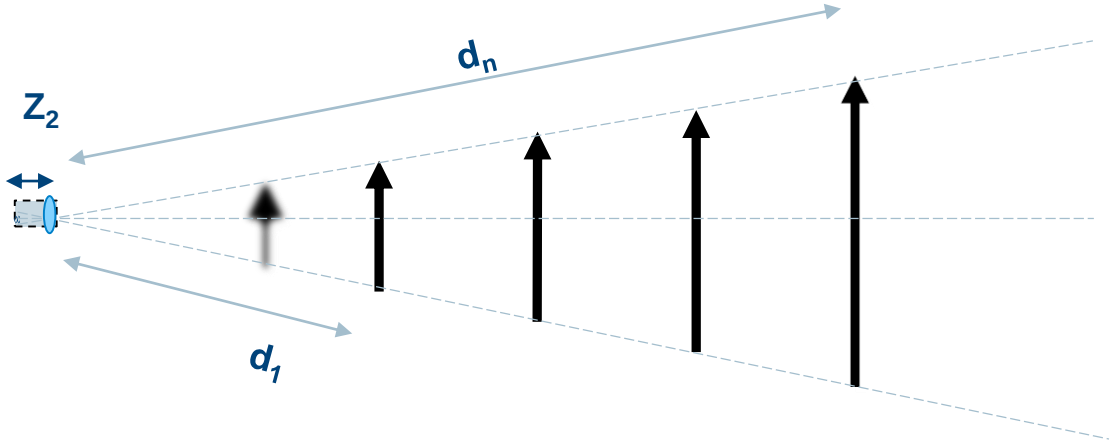


Micro - optics

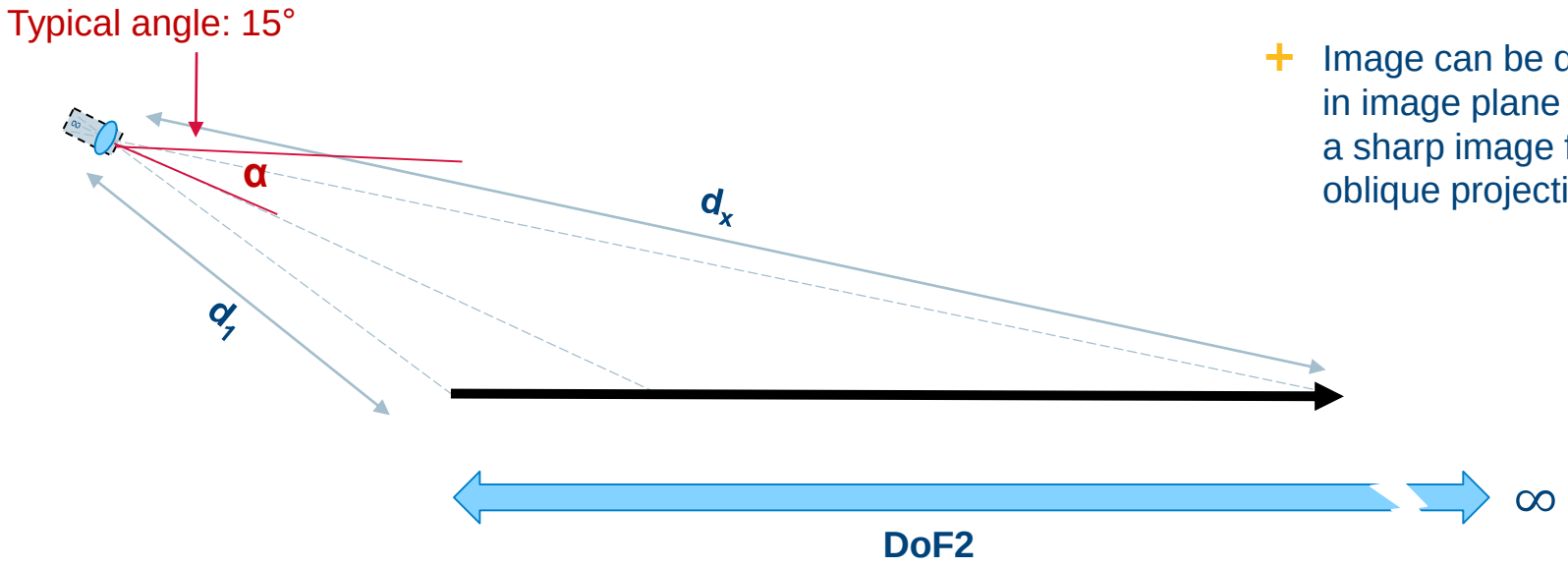


- \+ Reduced system size
- \+ Increased Depth of Field (DoF)

GRACING INCIDENCE

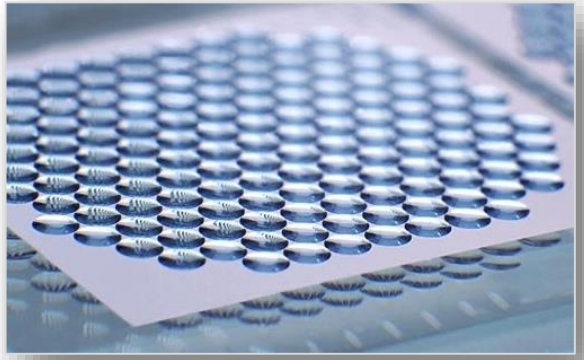


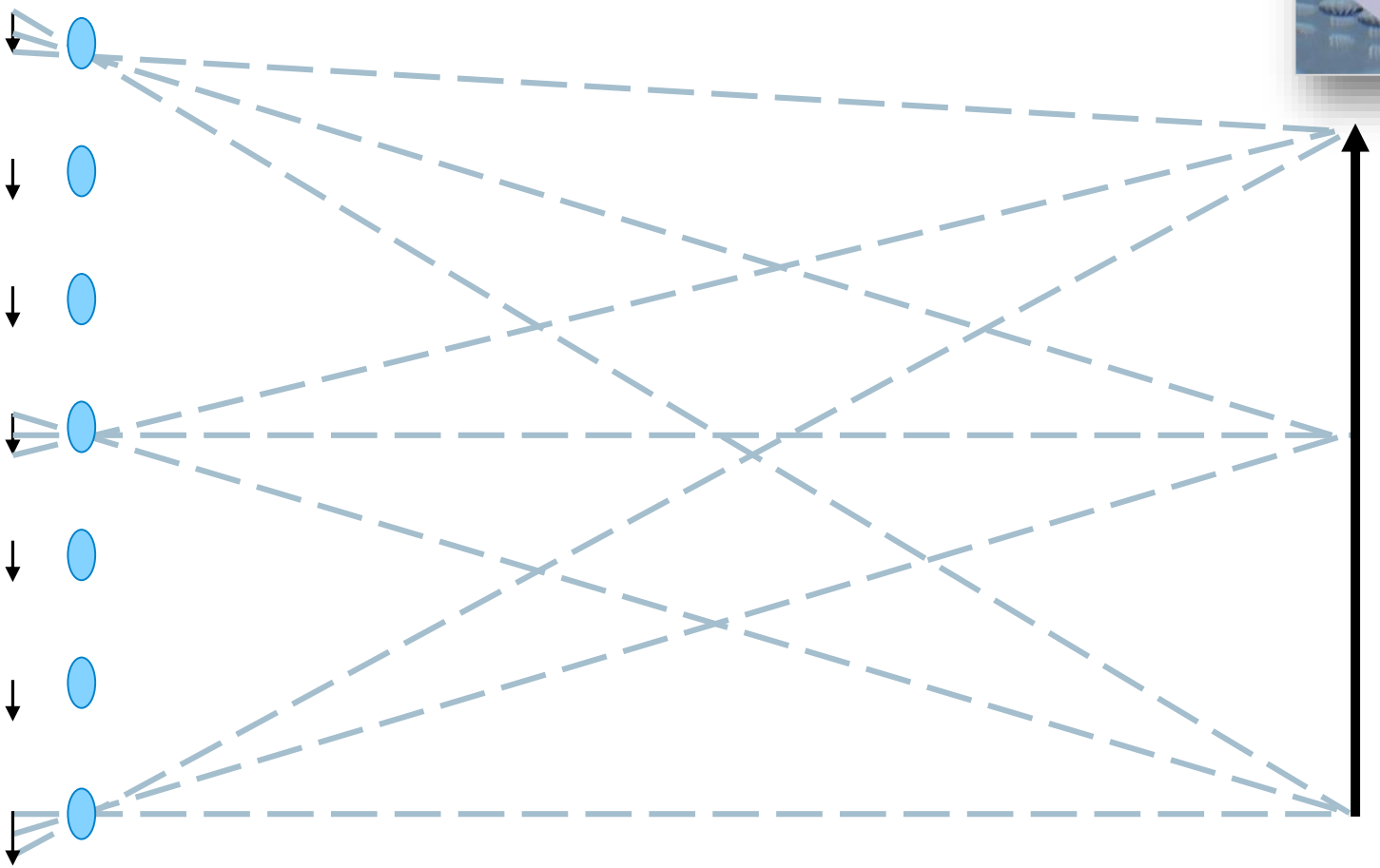
+ Sharp images for several Distances



+ Image can be distorted in image plane to create a sharp image for oblique projection

MICRO LENS ARRAY (MLA)





- Manipulation of Chromium Aperture
- Superposition leads to bright integral image
- Position of sharp image can be changed with different chromium apertures only

LIGHT CARPETS FOR DESIGN AND SAFETY

Future

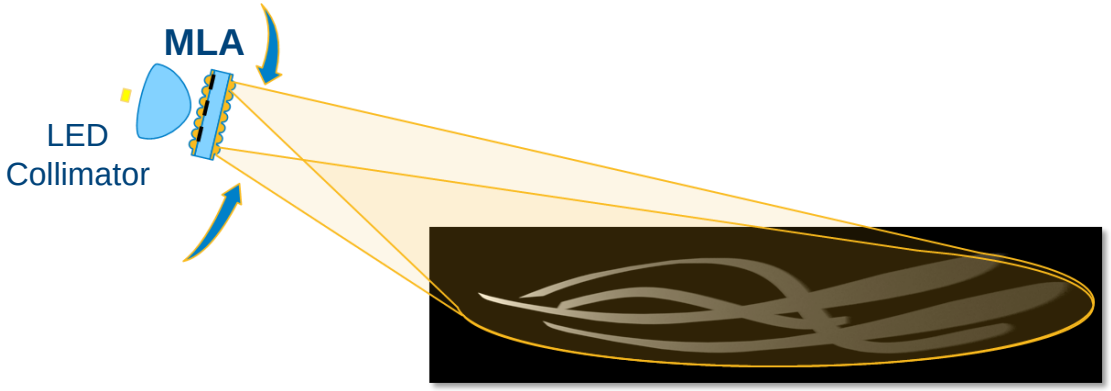
bmw.de, glowwing.com

LIGHT CARPETS FOR AUTOMOTIVE

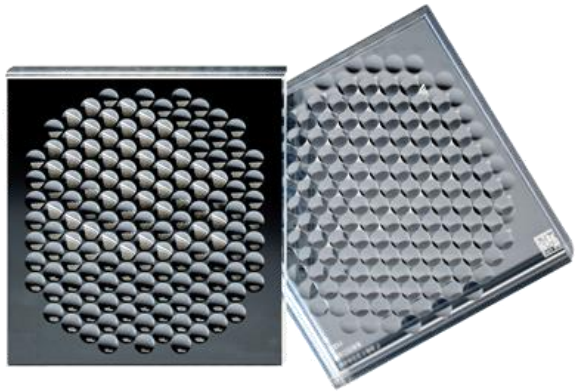
SÜSS MicroOptics

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

Mounting in the Rocker Panel

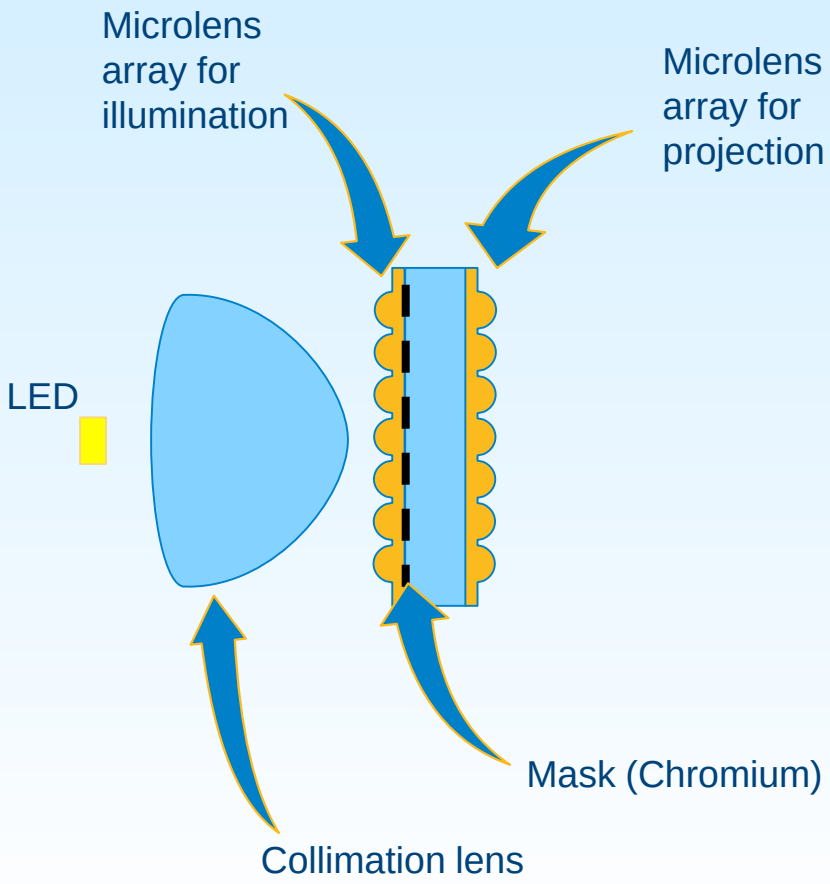


Projected Image

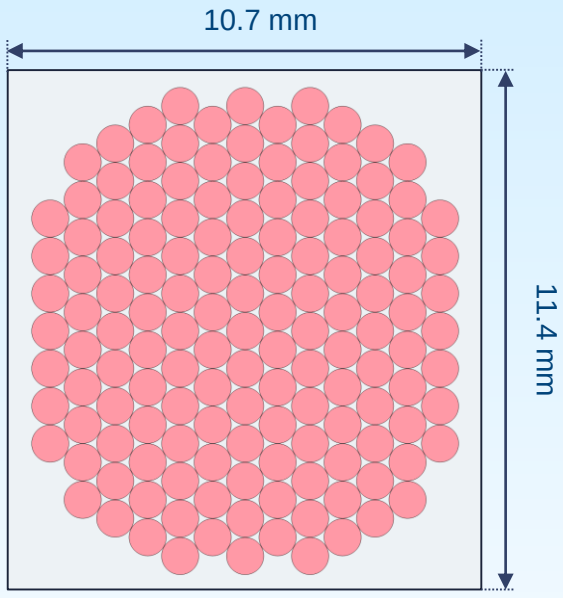


OPTICAL SYSTEM

Concept



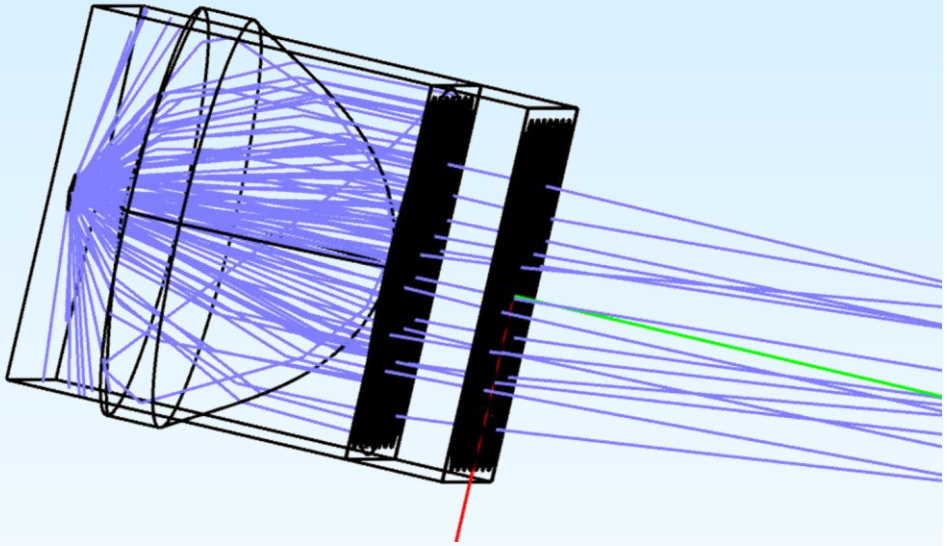
Geometry



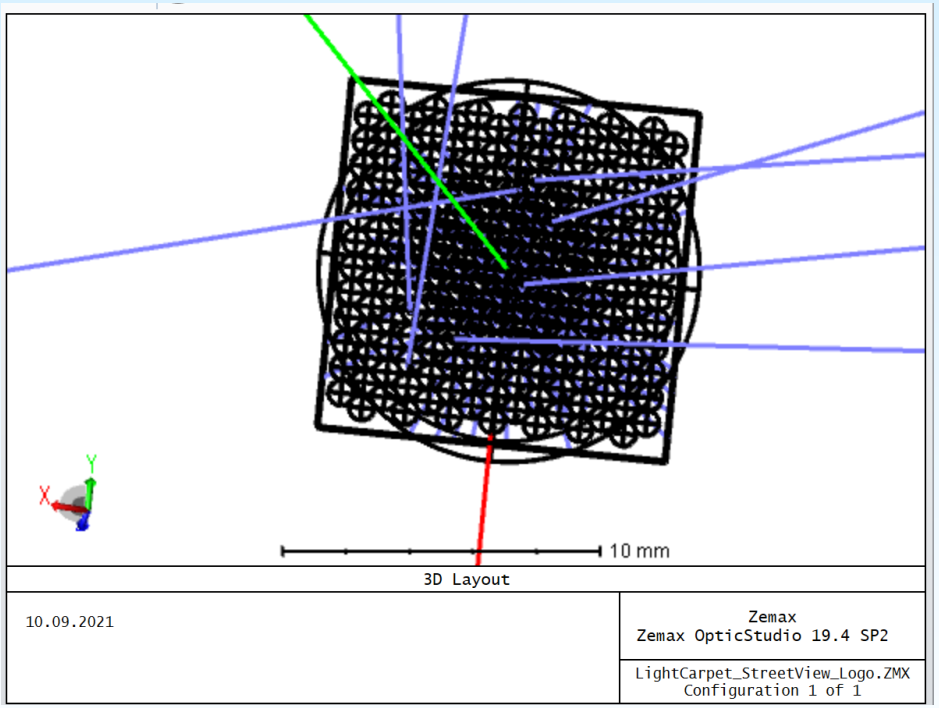
Microlens diameter: 800 µm

OPTICAL SYSTEM

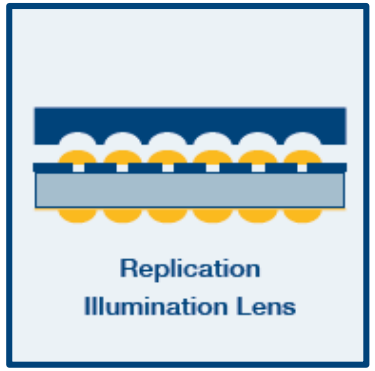
Concept

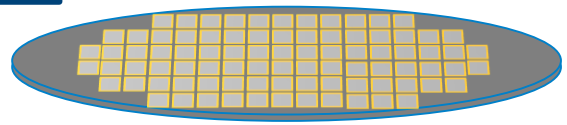


Geometry



PROCESS FLOW

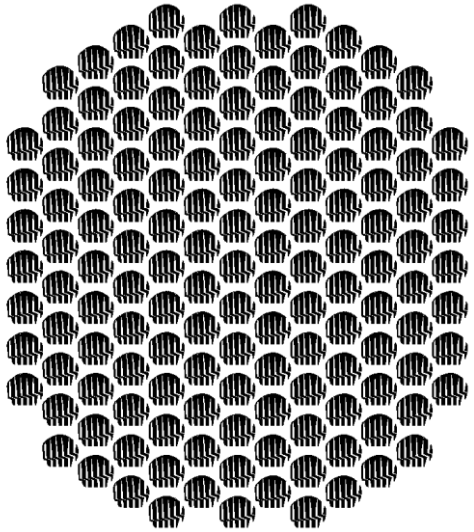




200 mm wafer-level process

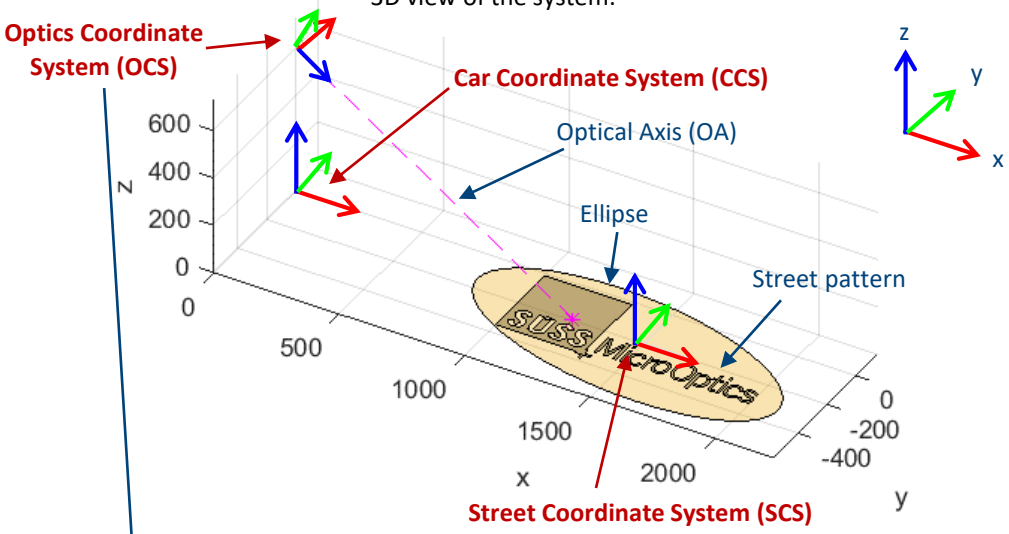
Iterations with the customer to reach the desired specs

Target configuration and pattern from customer → **Mask generation** → **OK for customer** → **Simulations and analyses** → **OK for customer** → **Tolerance simulations** → **OK for customer** → **Manufacturing of MLAs** → **Performance verifications** → **Shipping to customer**



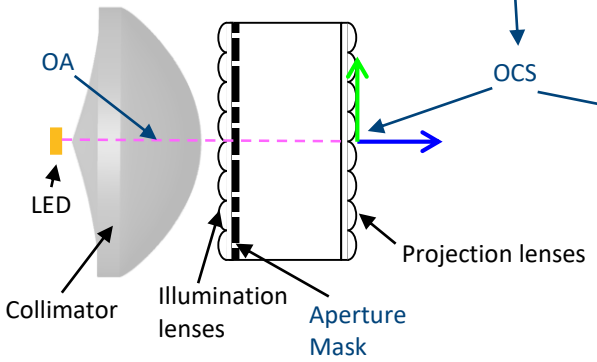
GEOMETRIC RELATIONS

3D view of the system:



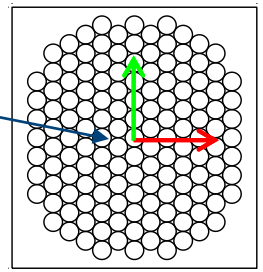
	X-center	Y-center	Z-center	Tilt about X	Tilt about Y	Tilt about Z
CCS	0 mm	0 mm	0 mm	0°	0°	0°
OCS	0 mm	600 mm	0 mm	152.826°	6.234°	-176.809°
SCS	200 mm	0 mm	-1300 mm	-90°	0°	-90°

MLA side view:



OCS

MLA front view:



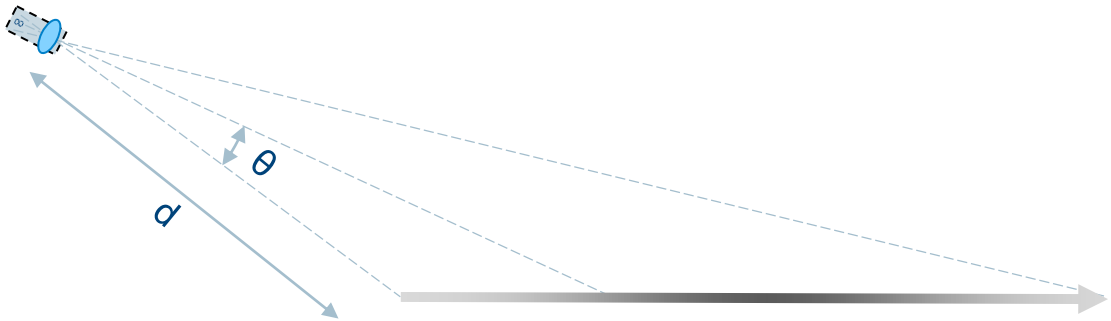
Geometrical description compatible with Zemax notation!

	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

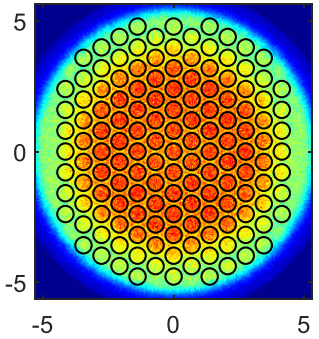
CUSTOMIZATION OF THE ILLUMINATION PROFILE

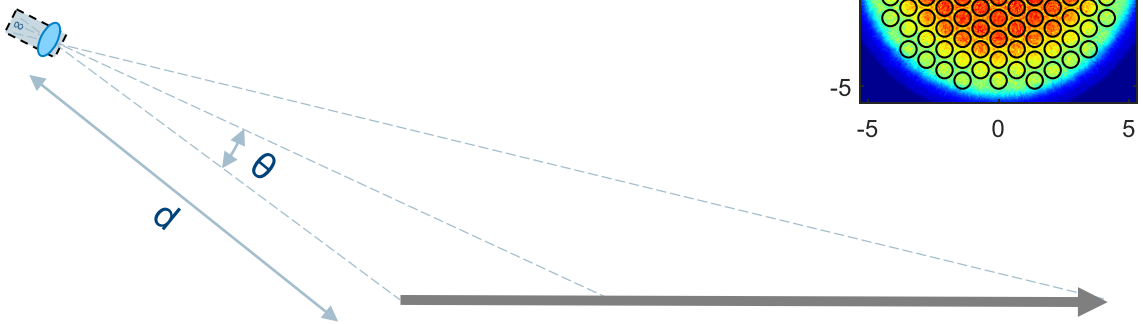
- Without any optimization, the illumination is not homogeneous because of the natural light decay:

$$I \propto \cos\theta / d^2$$

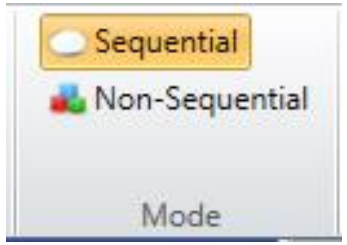


- It is possible to optimize the illumination to any custom profile. For example, by having a homogeneous illumination across the whole pattern.
- A Zemax simulation of the intensity in the different channels is required.

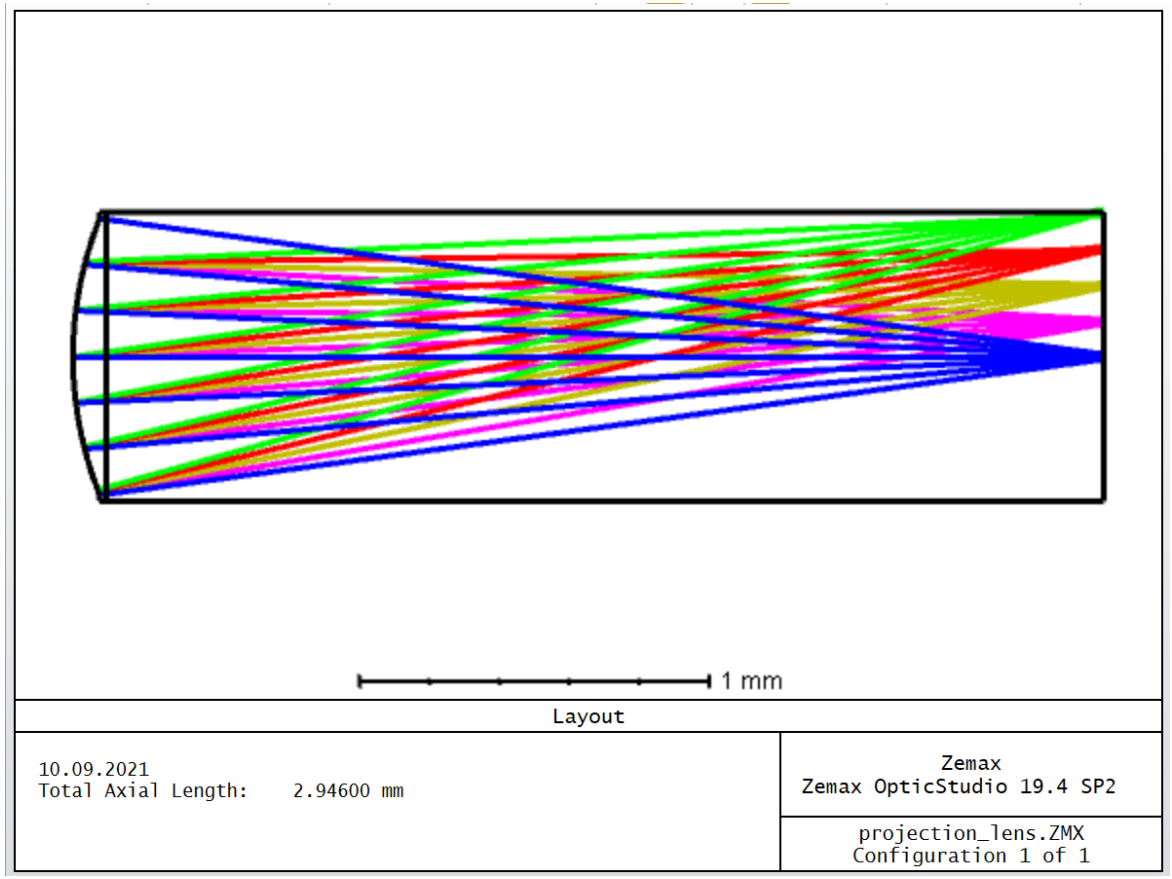




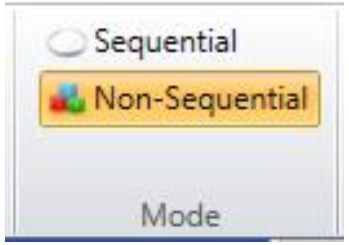
SINGLE CHANNEL OPTIMIZATION WITH SEQUENTIAL RAY-TRACING



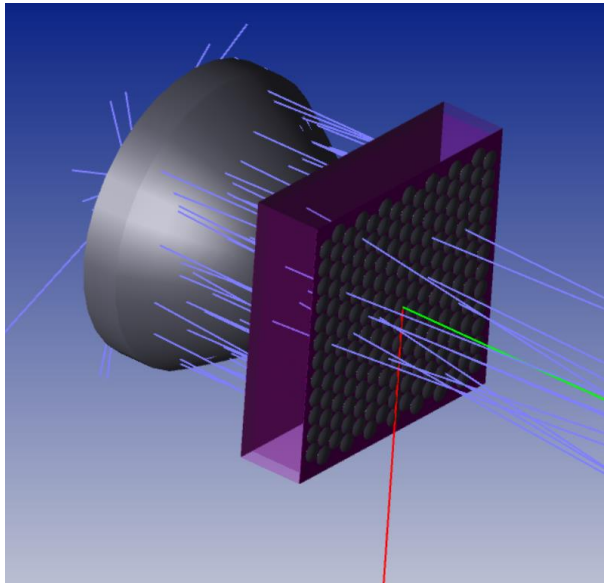
- Automated Zemax's macros
- Backward tracing (Zemax, post processing in Matlab)



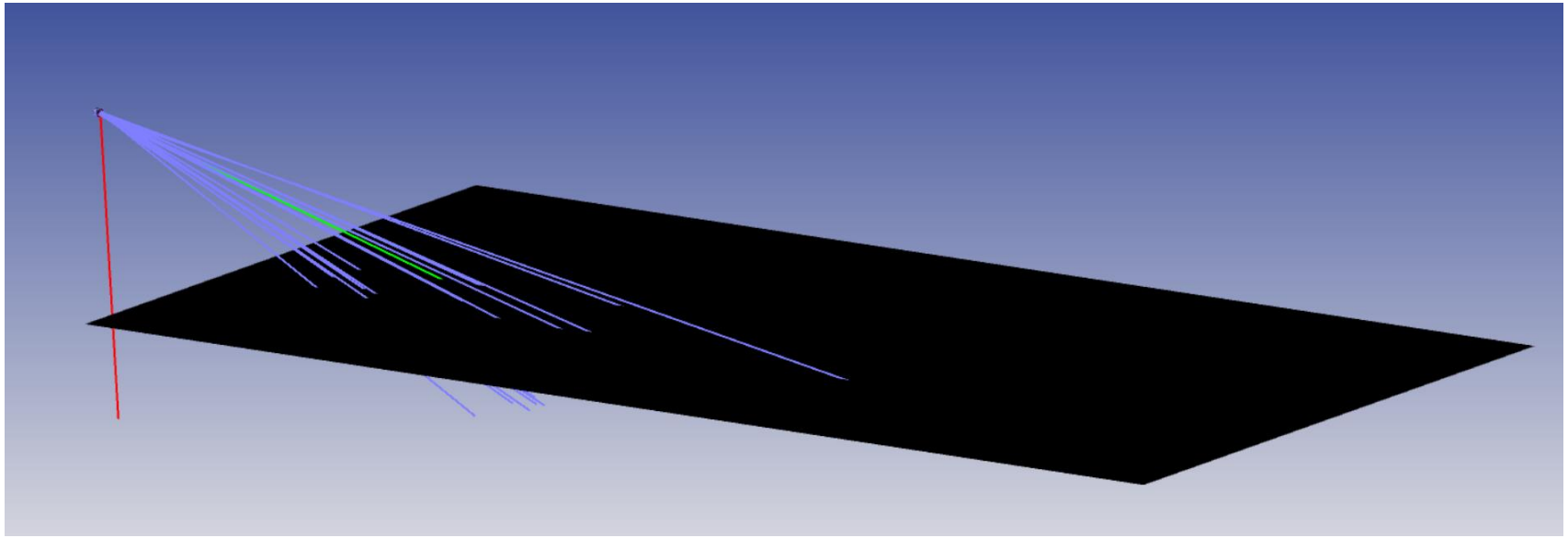
NON-SEQUENTIAL SIMULATIONS OF THE WHOLE OPTICAL SETUP



+ Module

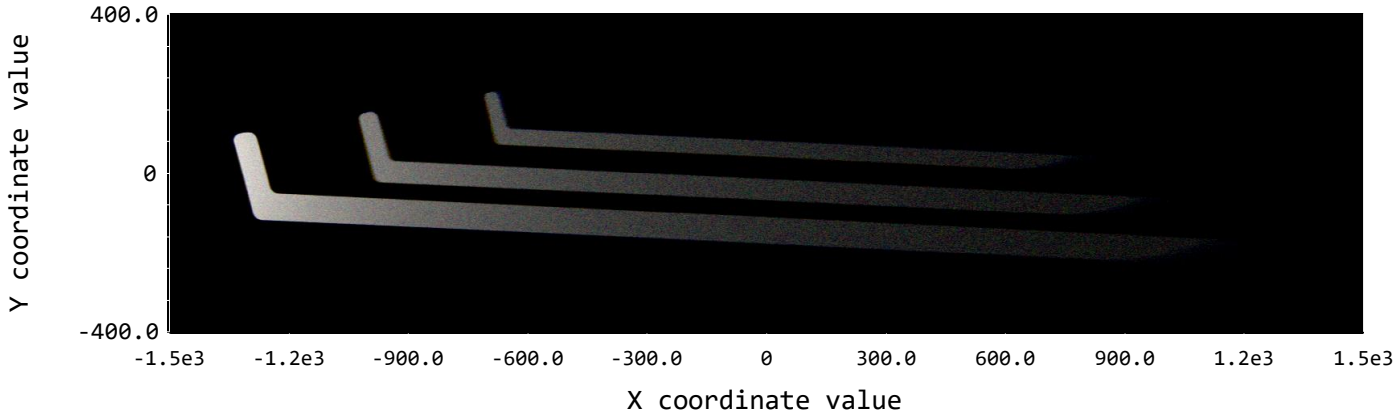


+ Overall Setup

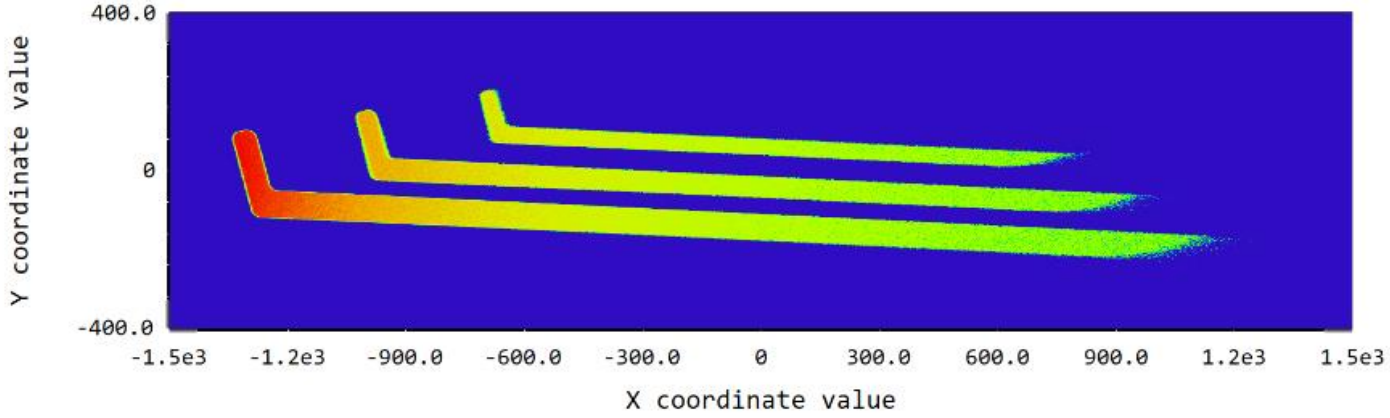


OPTICAL ANALYSES

+ True color



+ False color

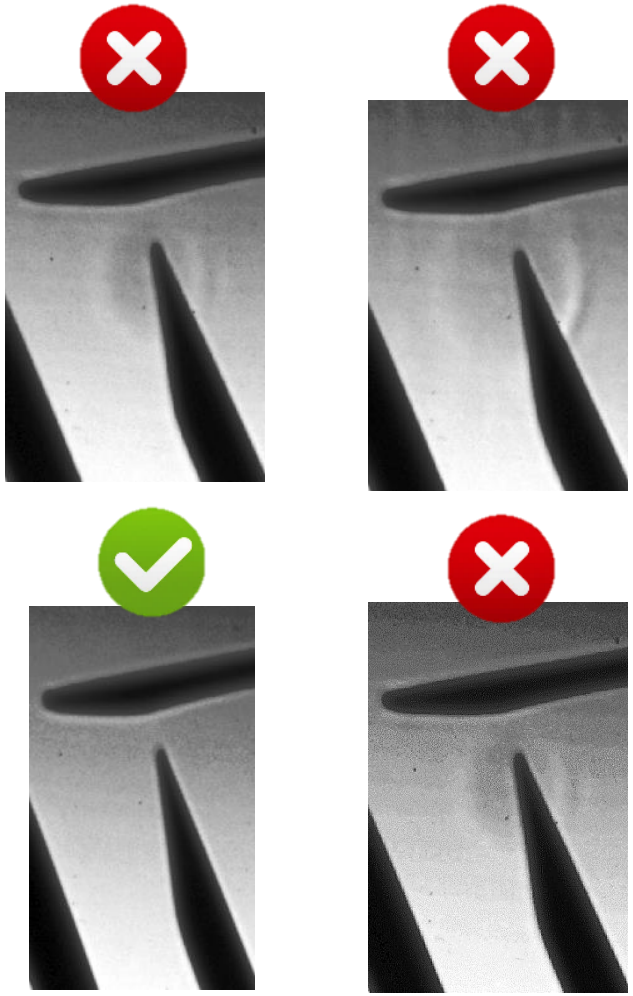


PATTERN RECOGNITION FOR SPECS VERIFICATION

Sharpness

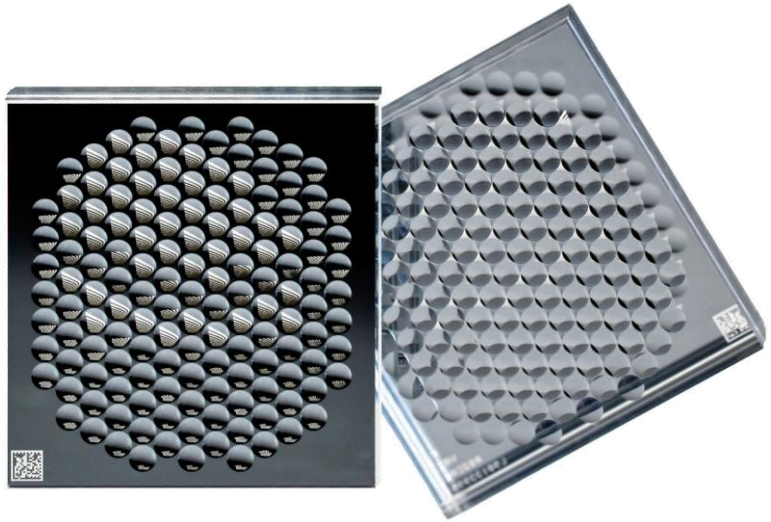
Background Uniformity

Local Defects



SO MANY PARAMETERS AND MERIT FUNCTIONS

- **Parameters with stochastic variations**
  - Lens shape:
    - Radius of curvature
    - Conic
    - Diameter
  - Lens variation within the MLA:
    - Lens shape
    - Lens pitch
  - Base-layer thickness
  - Wafer thickness
  - Misalignment:
    - X
    - Y
  - Rotation
  - Tilting
  - […]



- **System responses (merit functions)**
  - Luminance
  - Sharpness
  - Chromatic aberration
  - Uniformity
  - […]

LATIN HYPERCUBE SAMPLING

+ How to conduct a robustness analysis of the system?

Nested “For” loops

dreamstime.com

Monte Carlo Sampling

123rf.com

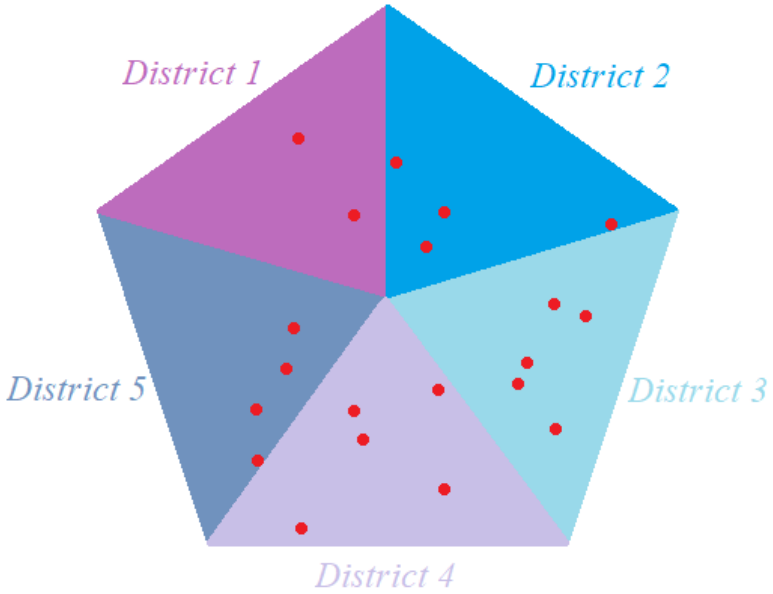
Latin Hypercube Sampling

gograph.com

LATIN HYPERCUBE SAMPLING

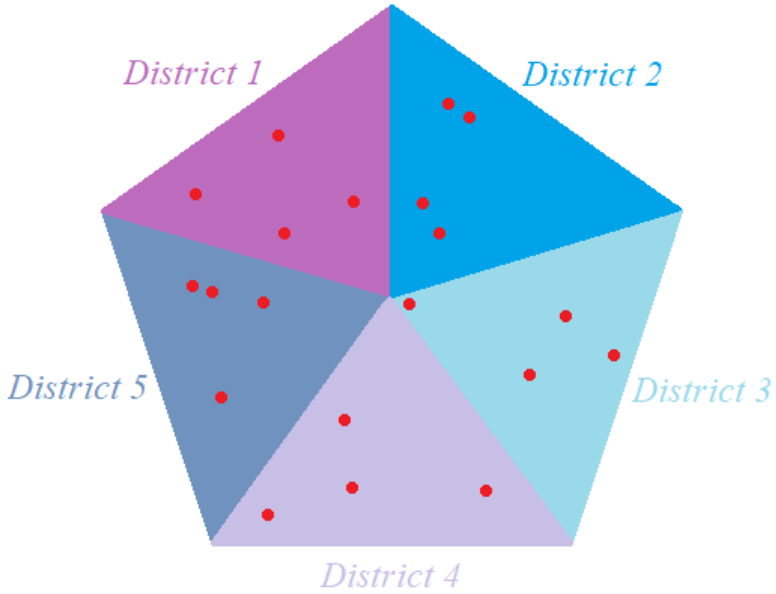
+ How to conduct a robustness analysis of the system?

Monte Carlo Sampling



Simple Random Sampling

Latin Hypercube Sampling

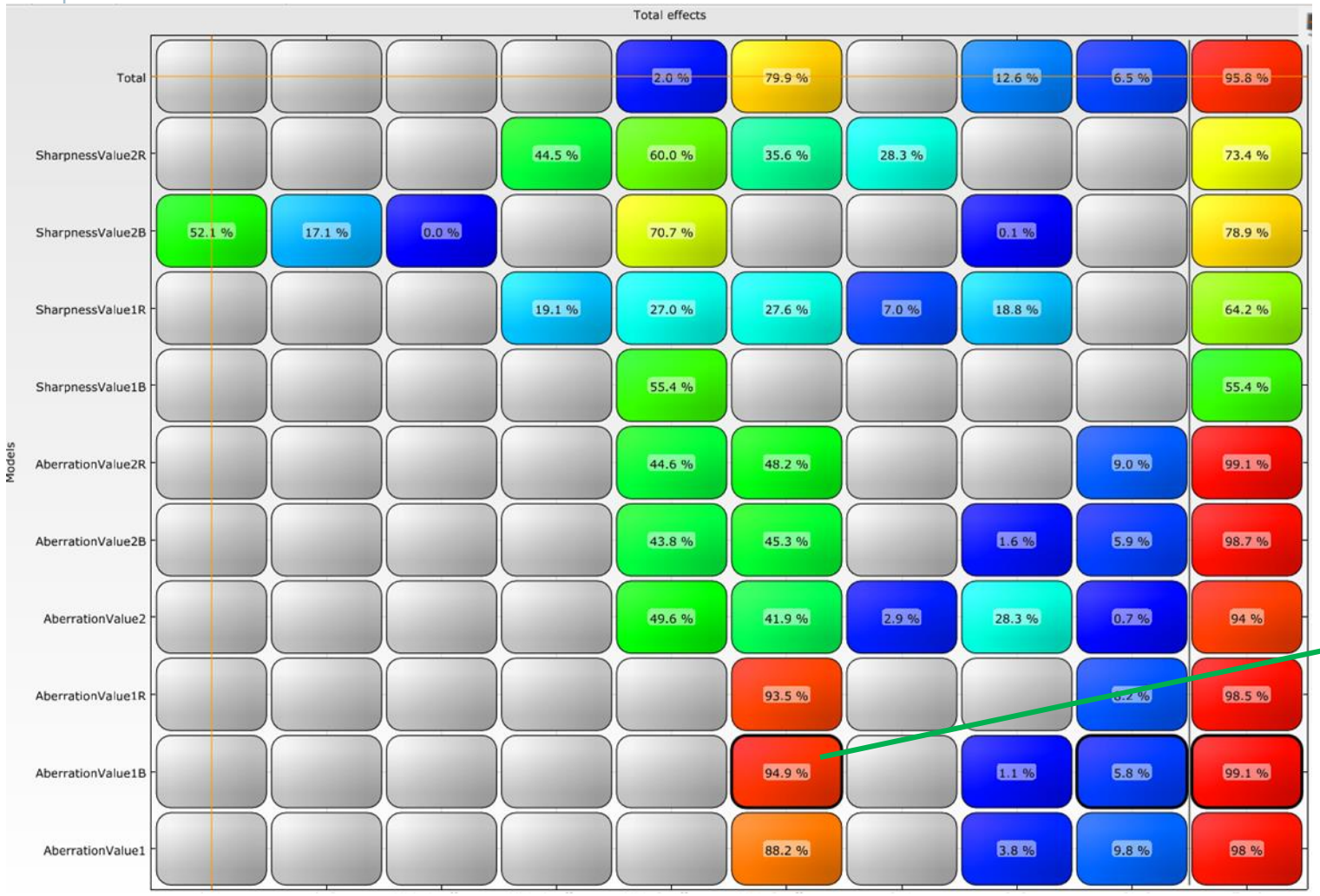


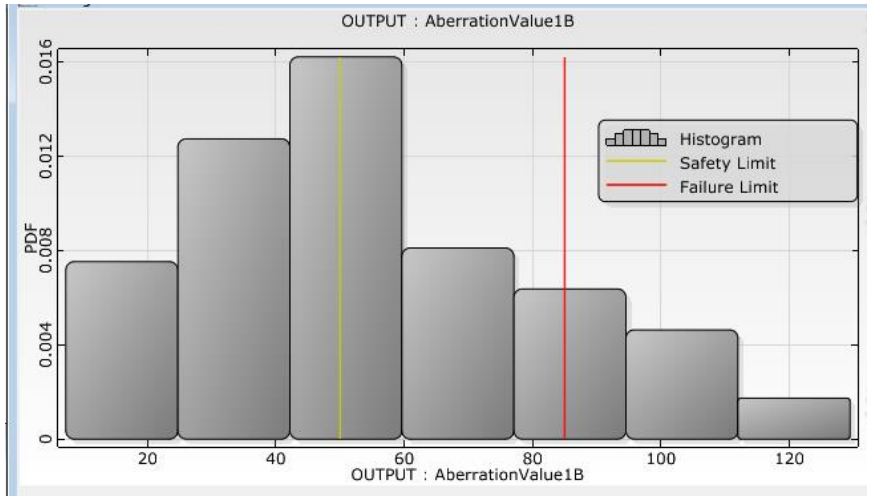
Stratified Sampling

datasciencegenie.com

COEFFICIENT OF PROGNOSIS (CoP) MATRIX

System responses





Parameters with stochastic variations

GIVEAWAYS AND WISHLIST

SÜSS MicroOptics

- **Microlens arrays** (MLAs) allow the creation of **slimmer designs**, have **high efficiency**, enable **advanced functionalities** and they allow more **freedom of design**.

- It is important to verify that an **optical design** is **robust against stochastic variations** during its manufacturing, because such a design may not be realizable in a production process.

- **Faster tracing** is always welcomed, especially for such “dense” simulations.

We are hiring!