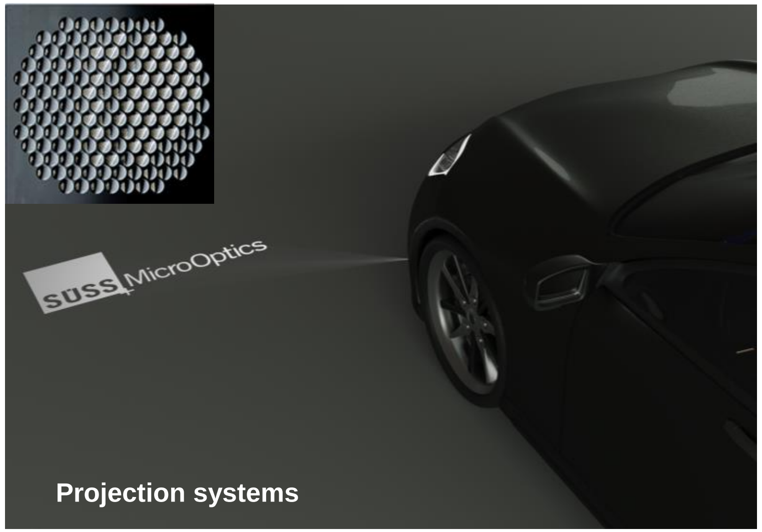
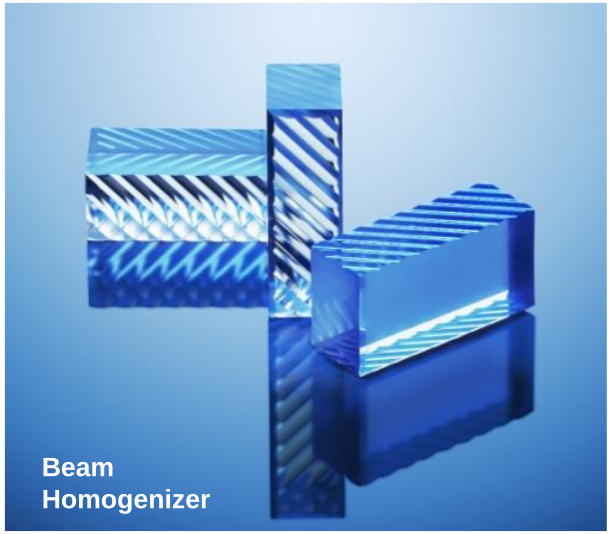
Challenges in Measurement and Characterization of Microoptical Components

Toralf SCHARF, Director Technology

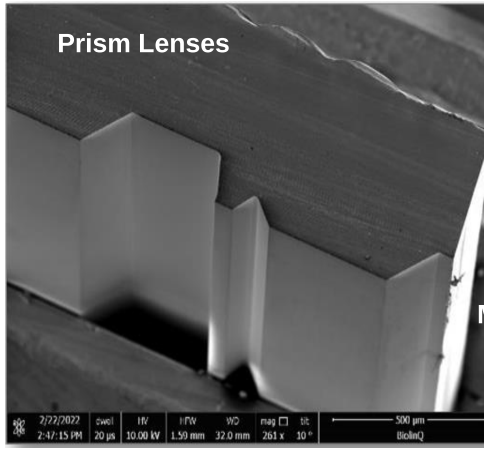
SUSS Micro-Optics at a glance



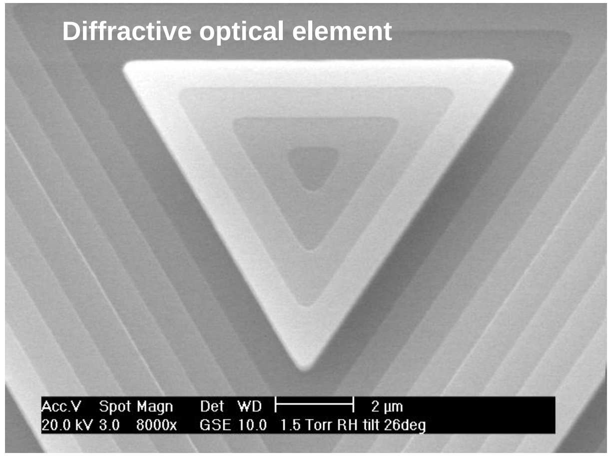
Projection systems



Beam Homogenizer



Prism Lenses



Diffractive optical element

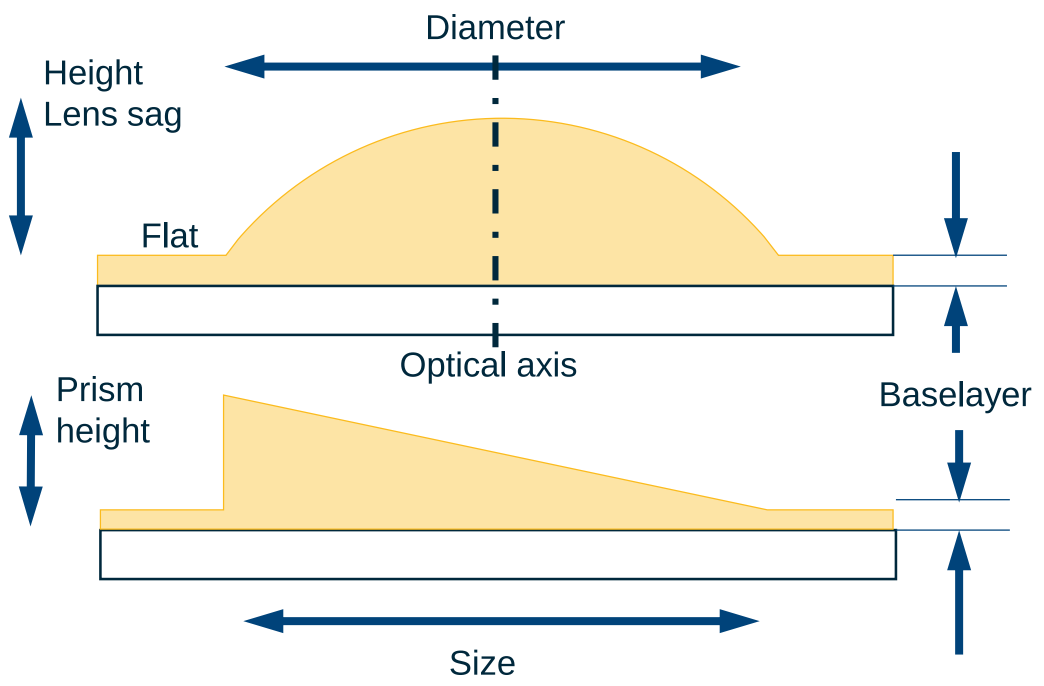
SUSS MicroOptics

135	**FTE** Our employees, mainly in production, R&D, marketing and sales
3,500	**m²** Production area at our location in Neuchatel, Switzerland
~41	**CHF million** FY2022 revenue with more than 150 customers
37	**CHF million** FY2022 order entry
>25	**%** CAGR in the last 4 years

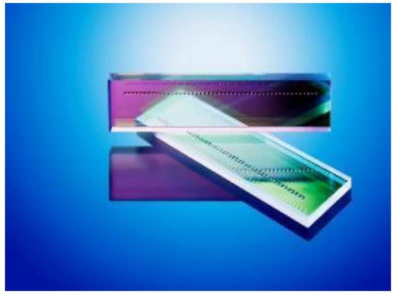
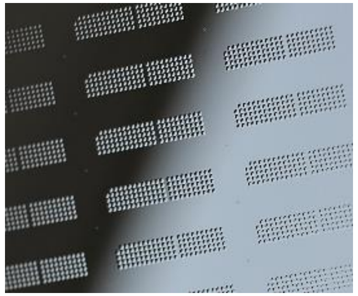
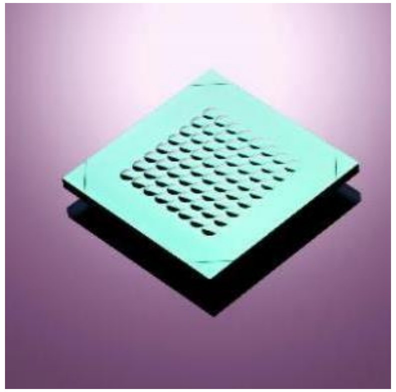
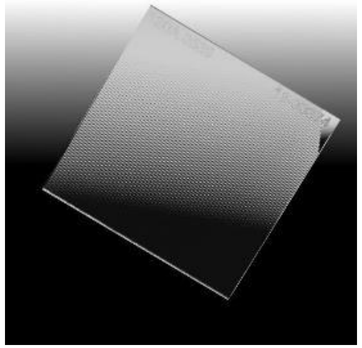
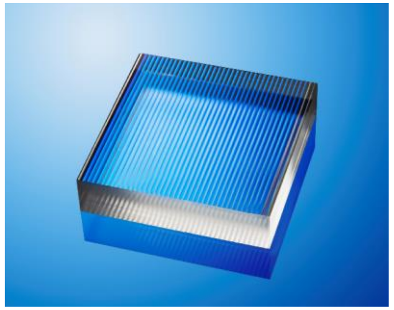
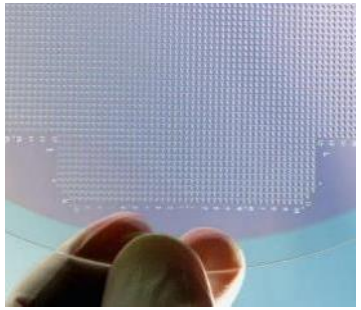
Typical microoptics objects

- **Microlenses**
  - Diameter (20 – 5000 micron)
  - Height (< 500 micron)
  - Form (spherical, conic, cylindrical…)
- **Diffractive optical elements**
  - Step height (from 10 nm to 500 nm)
- **Definition of surface shape**
  - For different surface models
  - Lenses: Conic surface with only a few constants (ROC, Conic height)
- **Recess or base layer**
- **Roughness**
- **Calibration**
  - Lateral dimensions, Step height

- Residual layer or base layer
- Surface shape irregularity RMS (< 20 nm)
- Surface shape irregularity (< 100 nm)
- Surface roughness < 5 nm



Microoptics Zoology

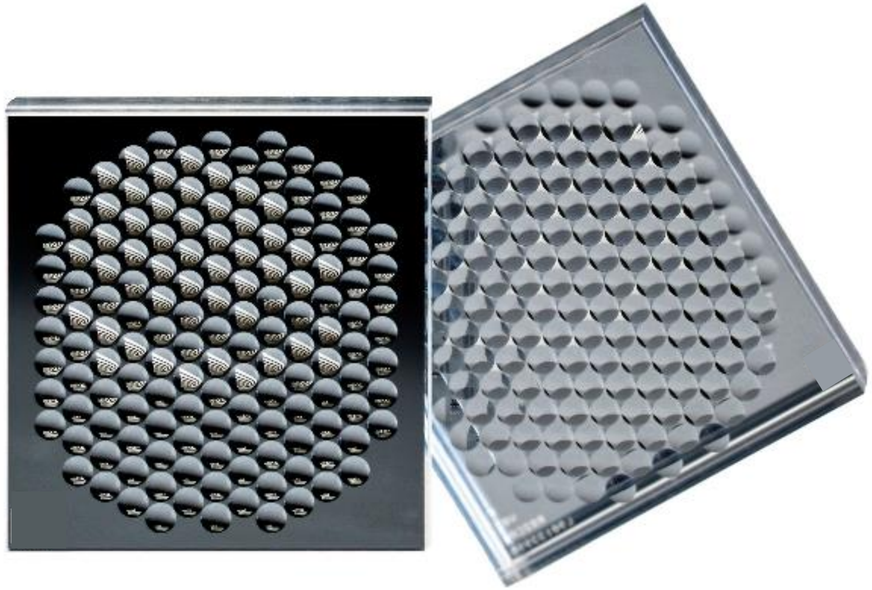
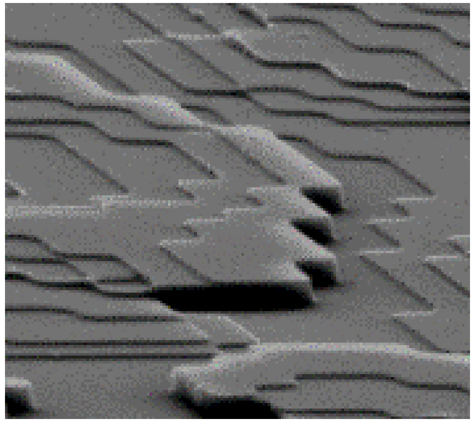
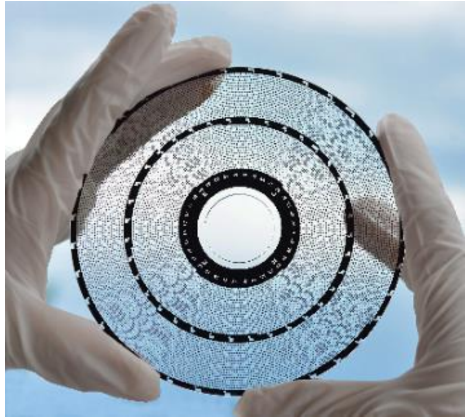







Technology

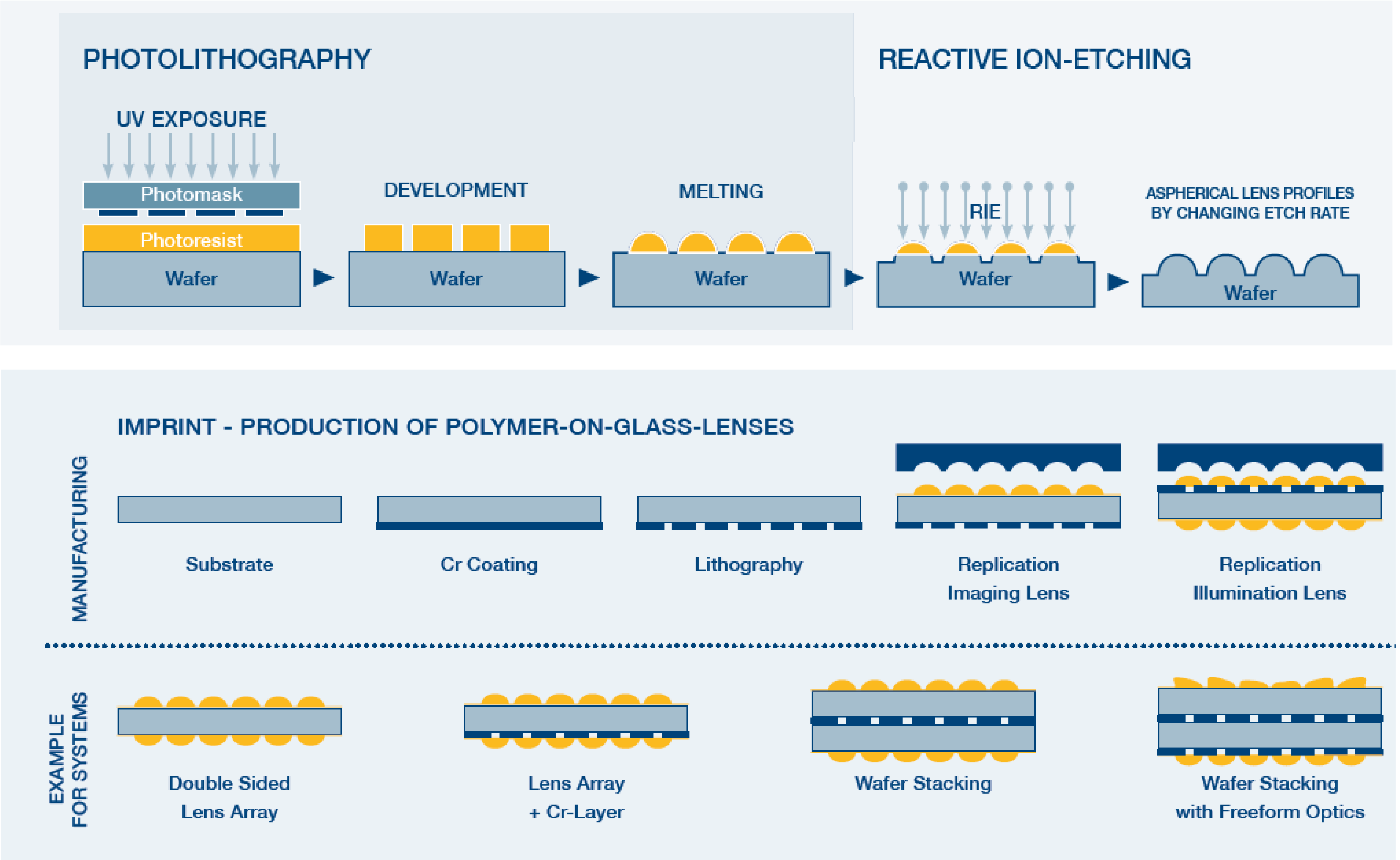
+ **Reflow**
+ **Etched**
+ Micromachining
+ **Imprinted**
+ Molded

Materials

+ **Photoresist**
+ **Glass**
+ **Polymer**
+ **Silicon**
+ Metal

Reflow & Reactive ION Etching and Imprint



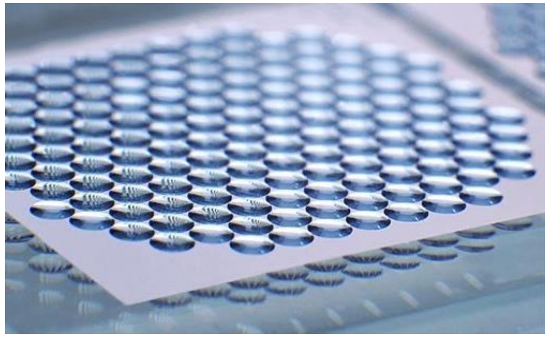
Standard Production

+ Aspheric and cylindrical lenses
+ Lens dimension below 1mm in diameter
+ Lens sag height below 100 micron
+ Si, SiOx…
+ Arrays of lenses with limited fill factor

Imprint

+ Aspherical cylindrical and freeform
+ Lens dimension below 5mm in diameter
+ Lens sag height below 500 micron
+ UV polymer (i.e Epoxy)
+ Arrays of lenses with 100% fill factor

Microoptics fabrication: Metrology tasks



Optical design

Wafer with apertures

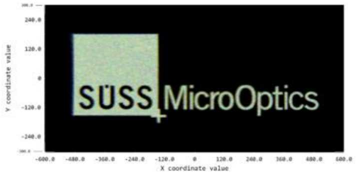
Master fabrication

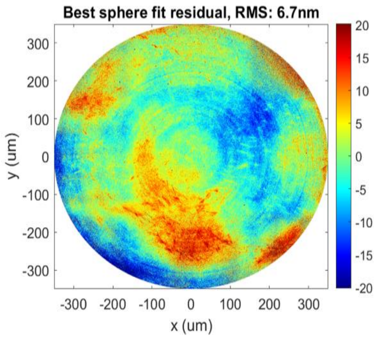
Tolerancing and calibration

Wafer Metrology

Master Metrology

Verification Simulation





Fabrication large area sub-master

Sub-master Metrology

Production

Stamp fabrication

Replication Assembly

Product Inspection

Inspection Packaging

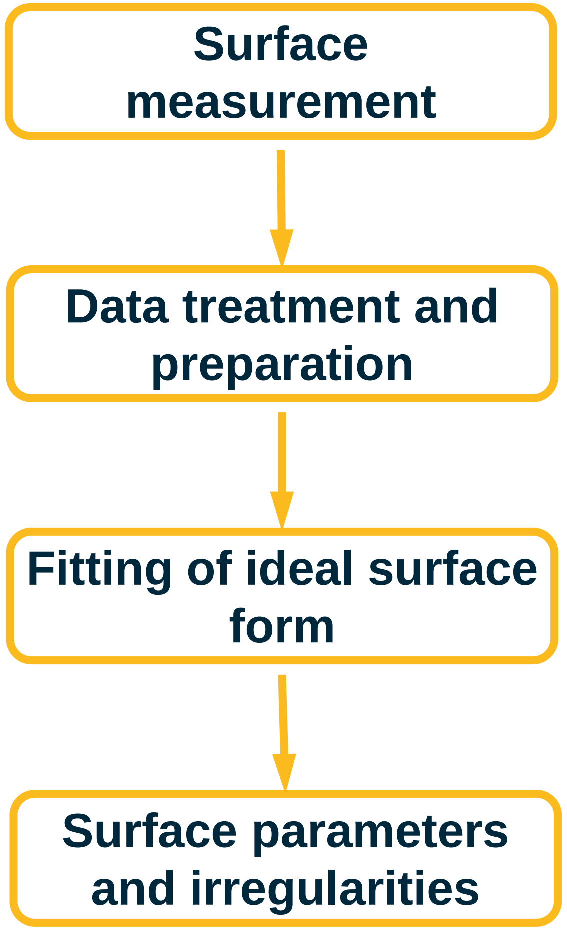
Dicing Separation

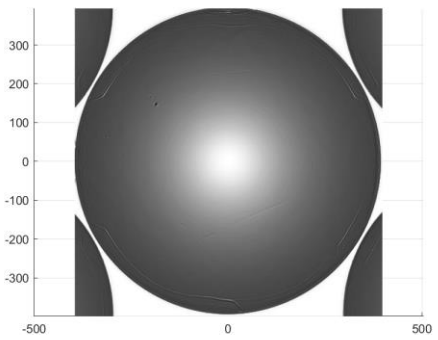
Functional Metrology

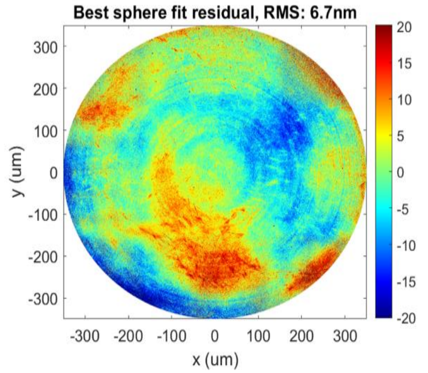
Surface Evaluation – Challenges

SUSS MicroOptics

- **Measure a surface**
  - Needs a calibrated measurement tool
  - Data handling for many measurement (> 30'000 lenses on a wafer)
  - Limitations of instrument (slope and resolution!!)
- **Compare with the design surface**
  - Needs a mathematical model of the surface
  - Evaluation parameters should be independent
- **Determine surface irregularities** (RMS values)
  - Result and quality of the fit
  - Important parameter for discussion with clients
- **Measure and calibrate according to know standards**

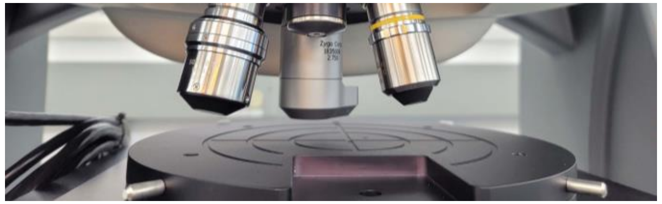






The ideal measurement tool for Micro-optics

- Measure **surface shapes** (according to client specifications)
- No contamination (contactless)
- **Fast** (measurement times well below 1 s per field of view)
- **Large field of view** for single shot measurements (> 1mm x 1mm)
- Allows to measure **high slope angles (> 45°)**
- Large substrates (300 mm) and possibility of stitching or scanning (measuring complete chips of dimensions about 10 mm)
- **Very high precision** (low noise values below 5 nm)
- Very high reproducibility (position and form)
- **Works for all surfaces** (materials such as Silicon, Fused silica and Polymers)
- **Calibration** (automatized and according to ISO standards)
- Internal data treatment with **evaluation software**
- Easy to use in different user modes (operators)



Measurement Tools – Operation principle

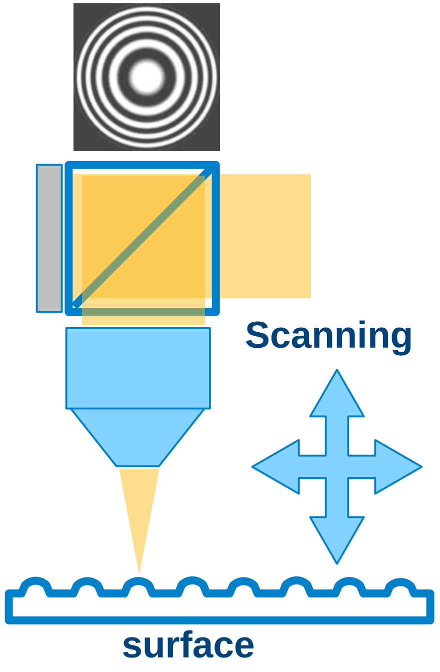
SUSS MicroOptics

+ Interferometry

White light (scanning) interferometer

PRECISE

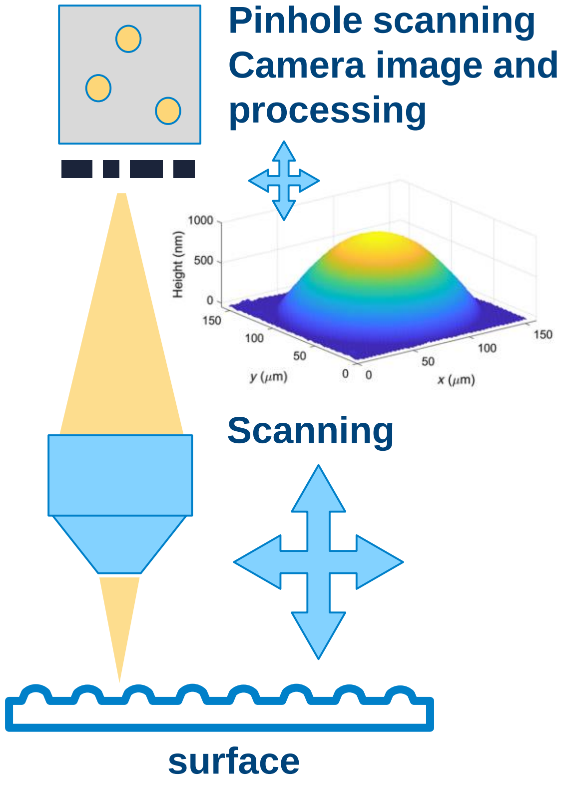
interferogram and processing



+ Confocal scanning

Confocal (focus point) scanning

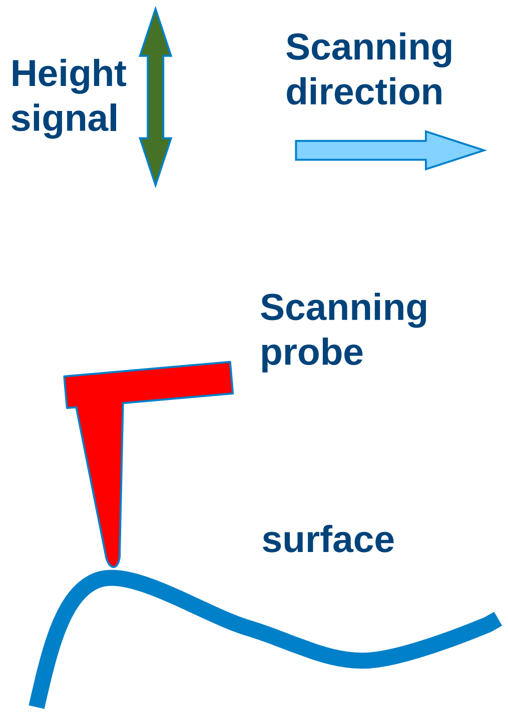
AFFORDABLE



+ Stylus profiling

Sphere moving over the surface (touching)

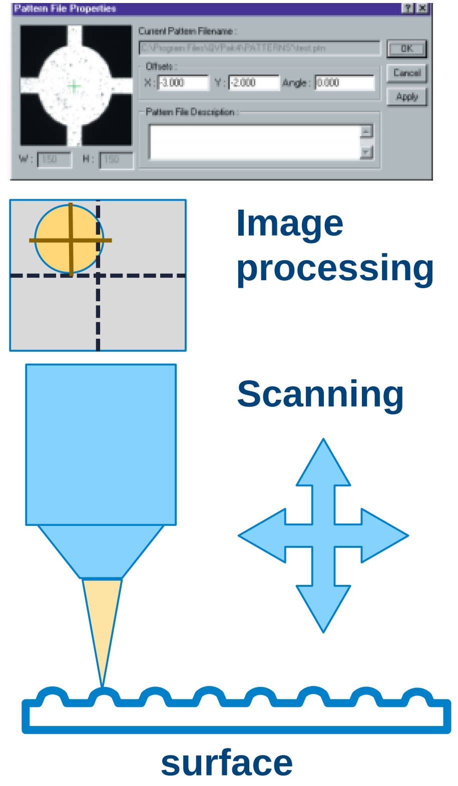
HIGH SLOPES



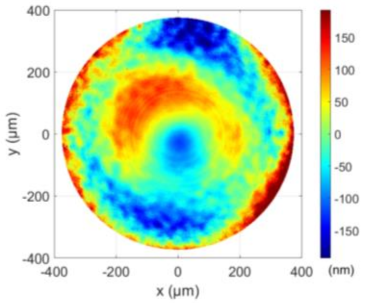
+ Coordinate

Microscope/image vision and precision stage

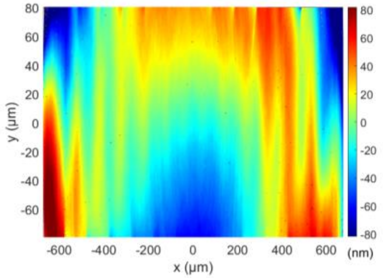
Large fields



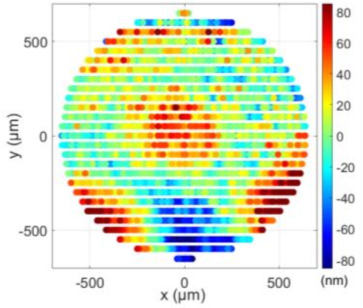
Example: Field of view limitations



µsurf 20x, RMS = 78 nm
Sampling x: 1.6 µm, y: 1.6 µm

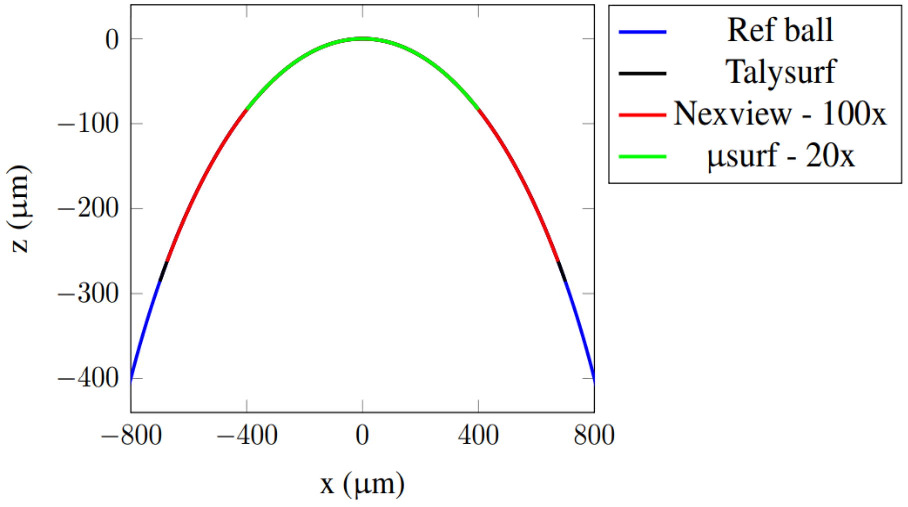


Nexview 100x, RMS = 34 nm
Sampling x: 0.17 µm, y: 0.17 µm

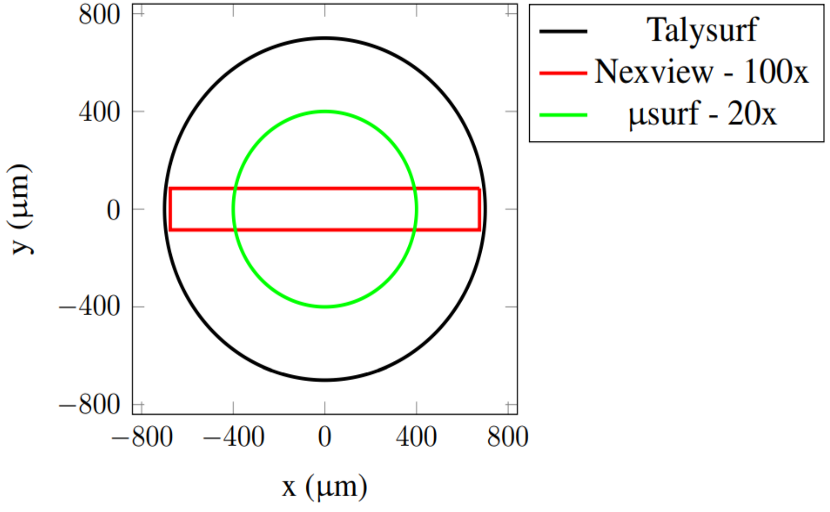


Talysurf, RMS = 55 nm
Sampling x: 10 µm, y: 40 µm

Comparison between three different measurement methods using three different instruments. The amount of information that is collected (surface area) and its quality (RMS value) are different from one method to the other, but the measurement time as well.



Surface measured profiles

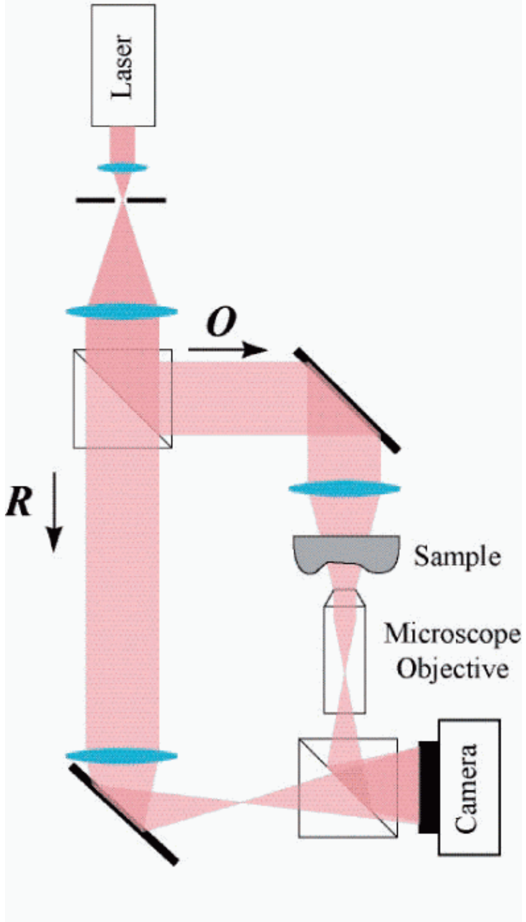


Top view: fields-of-views

Instrument	Measured dim. (µm)	Max slope	ROC (µm)	RMS (nm)	Time (min)
Nexview 100×	rect. 1350x160	43°	1001.2	34	5
Talysurf	diam. 1400	45°	1000.1	55	6.3
µsurf custom 20×	diam. 750	23°	1001.2	78	0.25

Example: Immersion technique - Lyncee Tec

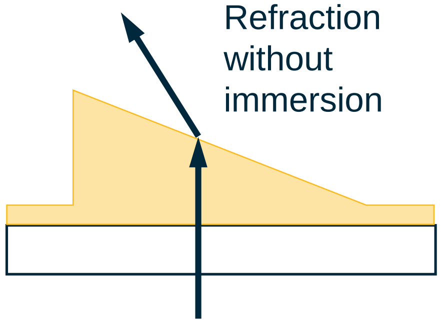
lyncée tec DHM®

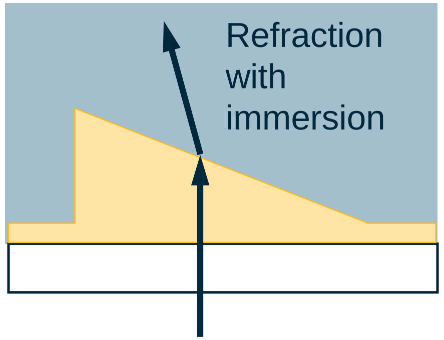


- DIGITAL Holographic microscope in transmission
- **Extremely fast** measurement time (<10 ms)
- The refractive index of object and environment plays a crucial role – changing the index allows to change the field of view
- Transmission measurement needs **TRANSPARENT subs**trates and structures (not for mastering)
- It is **NOT a surface characterization** but a FUNCTIONAL TEST
- It is **not traceable to conventional standards**
- Instrument of choice → **LYNCEE TEC digital holographic microscope https://www.lynceetec.com**

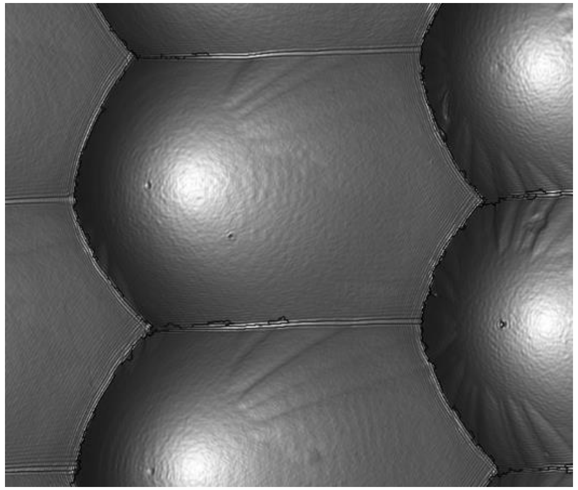
Extreme slope angles –immersion

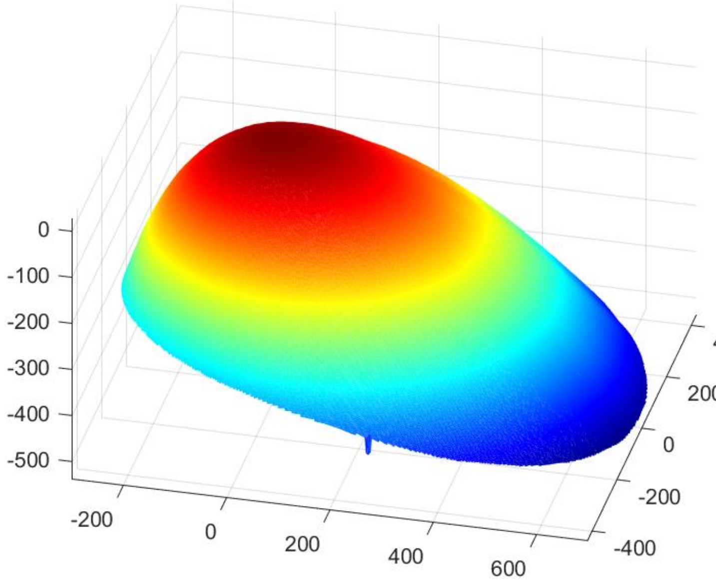
- Free form optical surface for illumination application with 73° slope angles
- Surface quality (roughness) and shape accuracy evaluation
- Method to be applied: Immersion digital holography





- Effective refraction angle is reduced
- A microscope objective with lower NA can be used which has larger field of view





+ Magnification 5x with **field of view of 1.2 mm square**
+ Index difference Δn= 0.037 (oil immersion, factor 13.97)
+ **Accessible mechanical slope angle for immersion ~ 75°**
+ **NO CALIBRATION ACCORDING TO STANDARDS!**
+ **MEASUREMENT NOISE IS AMPLIFIED**

- **Sample from Phabulous Project used case partner Zumtobel**

Situations for Freeform micro-optical surfaces

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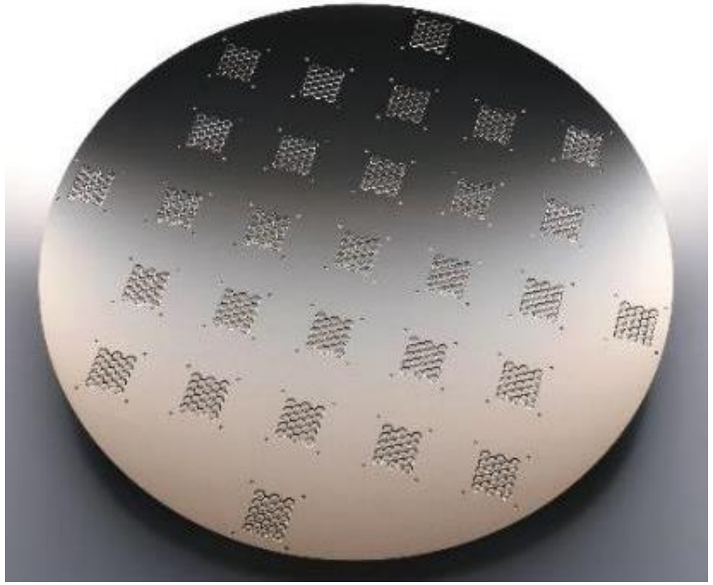
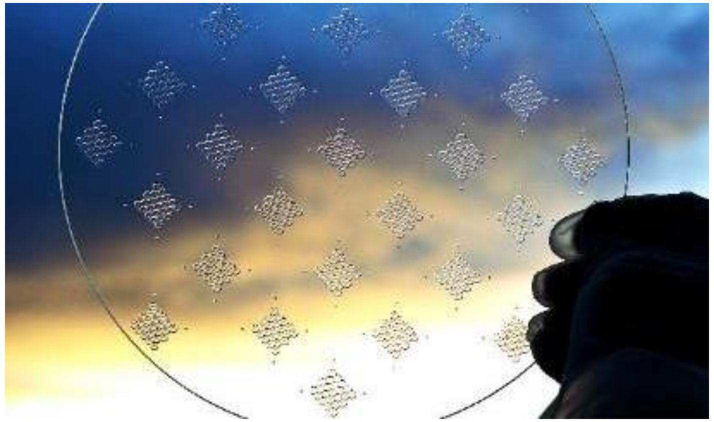
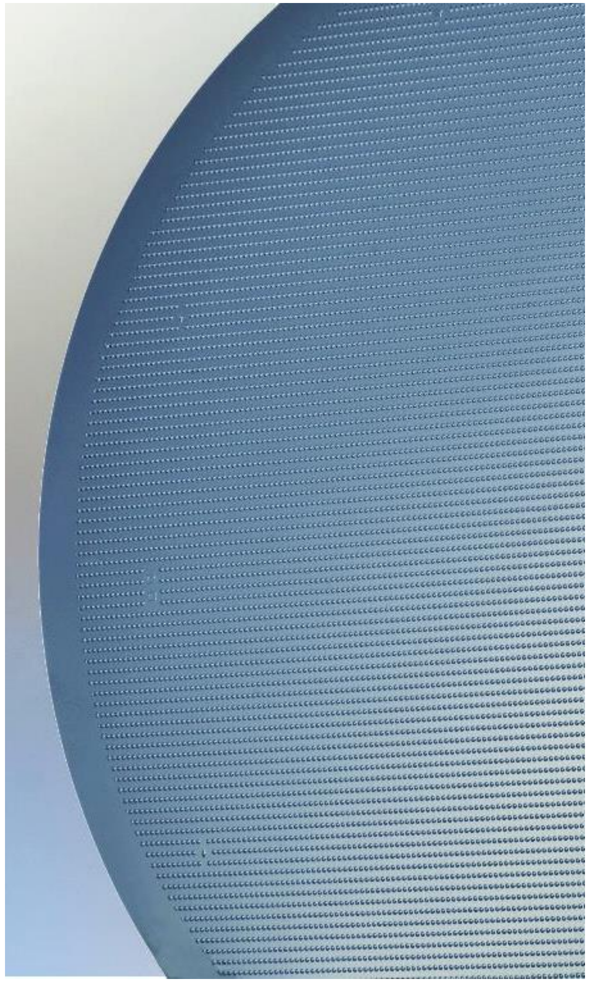
- Free form surfaces do **not have simple parametric descriptions** that allow easy fitting.
- Densely packed optical structures with 100% fill factor do not have a reference flat and the **definition of optical axis is problematic**.
- **Identification of optical unit** in packed optical structures is difficult when alignment marks are not in the field of view or simple not available.
- **Slope angles** for freeform surfaces can be very high and often reach the limit of instruments.
- **Optical function of freeform elements can be distributed over the whole array.** Special attentions is needed to the ensemble of elements.



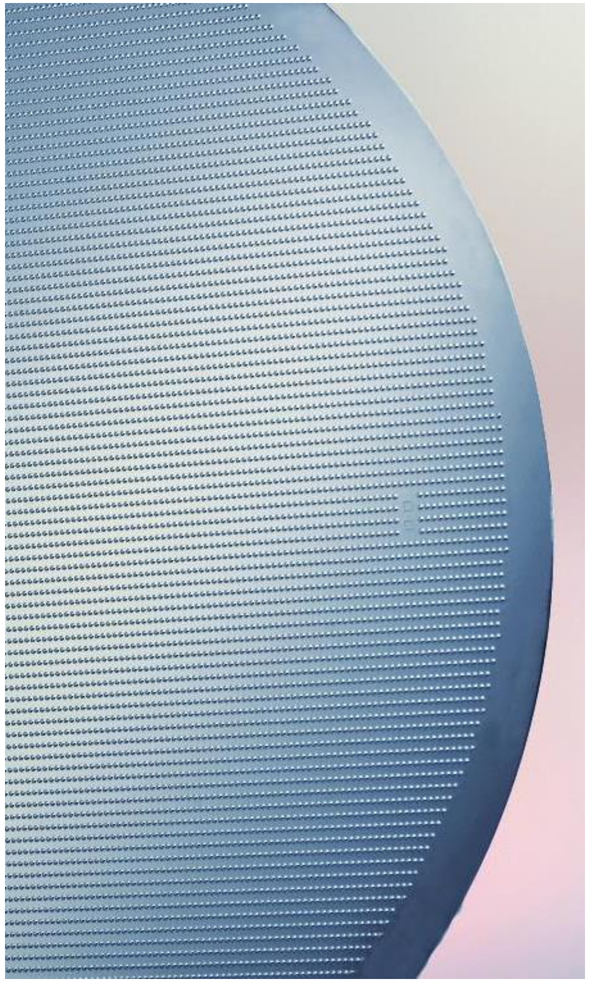


- **Sample from Phabulous Project prepared by Wielandts UPMT**

Conclusion



- Measuring microoptical structures is different from standard optics qualification because of small size of the object and the need of microscopic observation.
- Magnification optics causes problems because of field of view and slope angle limitation.
- Aberrations of microscope objectives deteriorate the quality of measurement and needs careful calibration.
- For Mircooptical arrays measurement need to be very fast to measure all objects
- There are no tools that can do all and a mix of different techniques leads to sever problems in comparing results.



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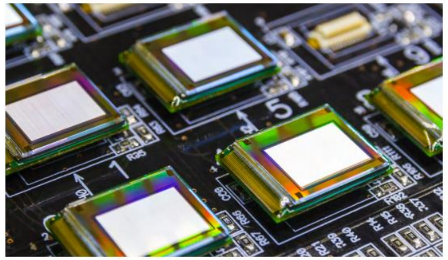
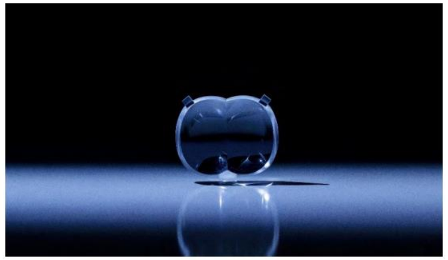
SÜSS MicroOptics

- Pilot-line providing highly advanced & robust manufacturing technology for optical free-form micro-structures
- PHABULOμS is an EC funded initiative, in a public-private partnership with Photonics21. (www.photonics21.org)
- The project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement nº 871710.


Automotive lighting


Micro-displays


Virtual reality


Solid-state lighting

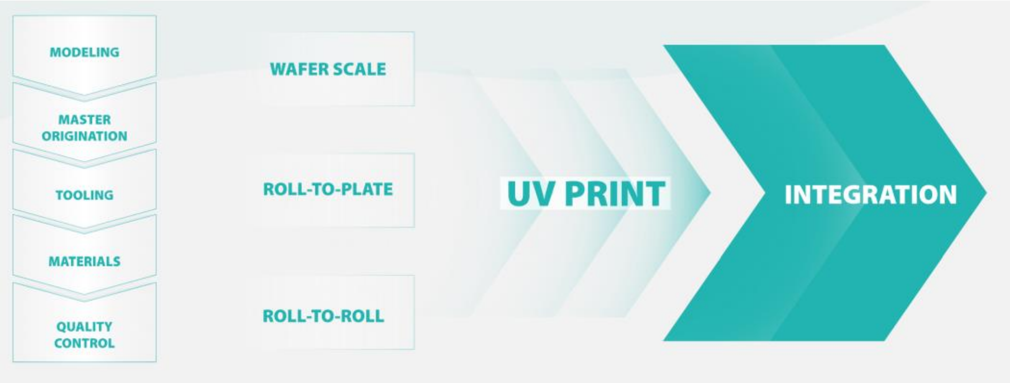

Luxury


Transportation interior lighting

Phabulous Pilot line

Pilot-line providing highly advanced & robust manufacturing technology for optical free-form micro-structures

https://phabulous.eu/



This project has received funding from the European Union’s Horizon 2020 research and innovation program under the Grant Agreement nº 871710, in Public Private Partnership with Photonics 21 (www.photonics21.org)

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Thank your for your attention!

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