



3D Printing for Advanced Glass Miniaturized and Micro- Optics

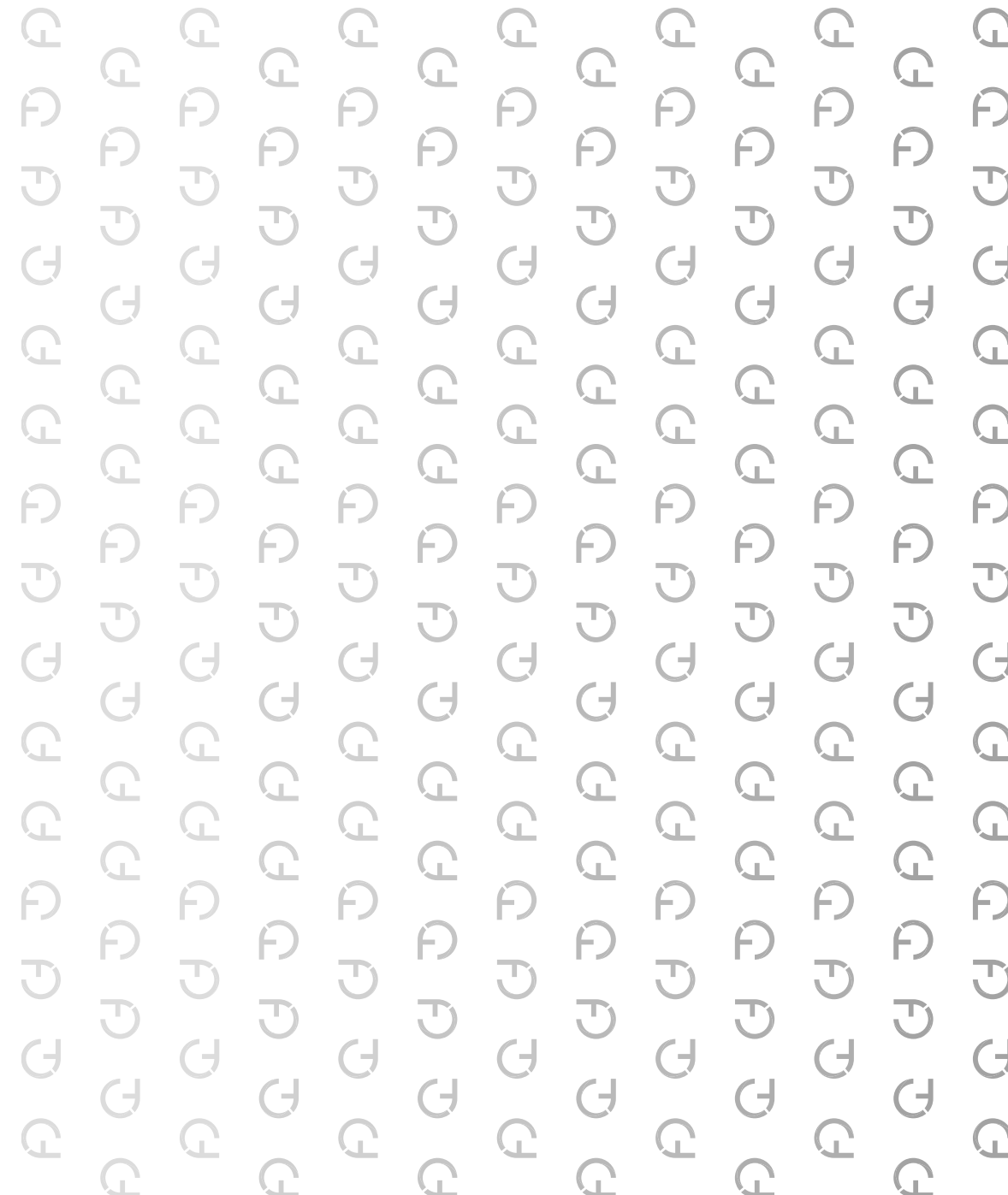
Dr. Rolando Ferrini & Dr. Andrea Lovera



Advanced Microoptics: Simulation, Fabrication & Characterization

Nanoscribe – Karlsruhe, May 11th-12th, 2022

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FEMTOprint IN A NUTSHELL

FEMTOprint is a Swiss high-tech Contract Development and Manufacturing Organization (CDMO) specialized in **high-precision 3D microfabrication in glass**.

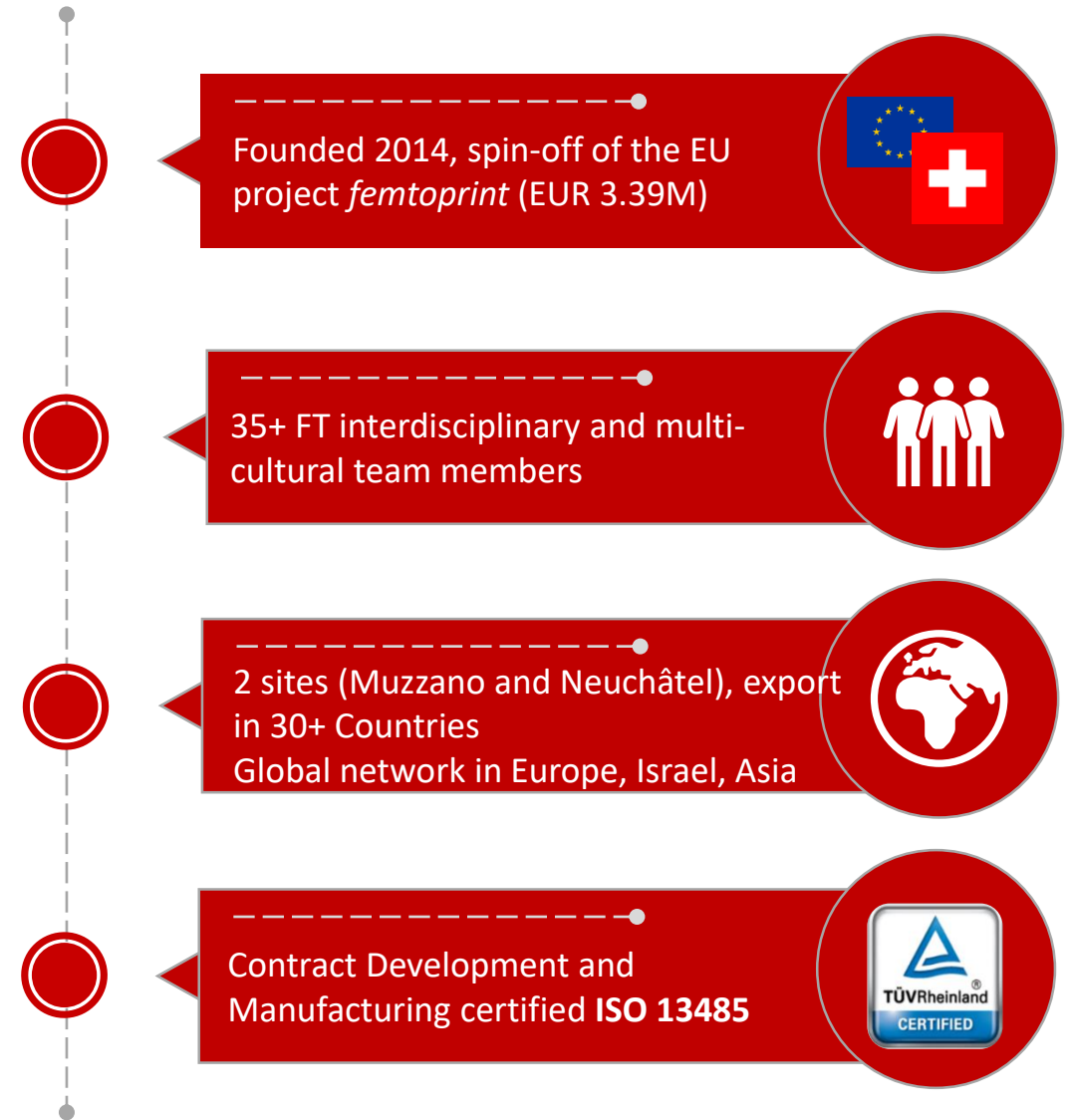
With the groundbreaking **FEMTOPRINT**[®] microfabrication platform we serve leading industrial customers with **feasibility, rapid prototyping, pilot- and industrial series manufacturing at wafer-level**.

APPLICATIONS

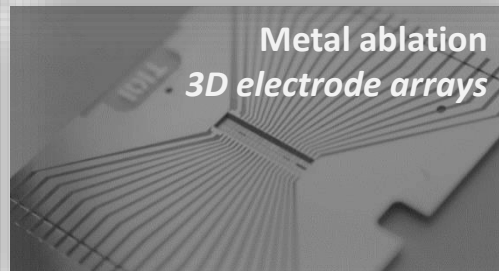
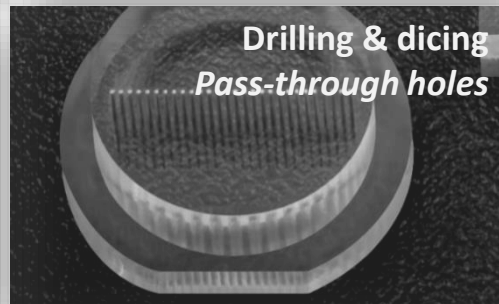
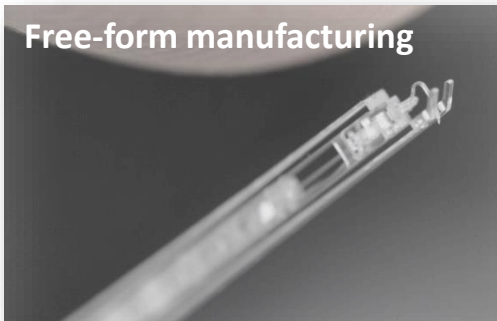
*Microfluidics | Microoptics | Photonics | Microelectronics |
Micromechanics | MEMS | Packaging | Mastering*

INDUSTRIES

*Life Sciences & Diagnostics | Medical | Watchmaking Aerospace &
Defense | Automotive | Industrial Machinery Precision Mechanics |
Semiconductors | VR & AR | Sciences*



CAPABILITIES



PERFORMANCES*

RESOLUTION AND TOLERANCES

- Process resolution $\sim 1 \mu\text{m}$
- XY tolerances $\pm 1 \mu\text{m}$
- Z tolerance $\pm 2 \mu\text{m}$

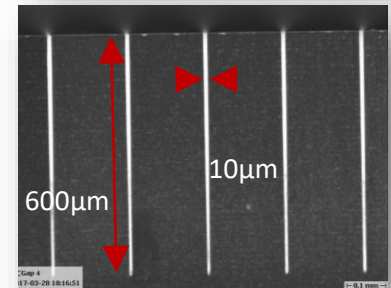
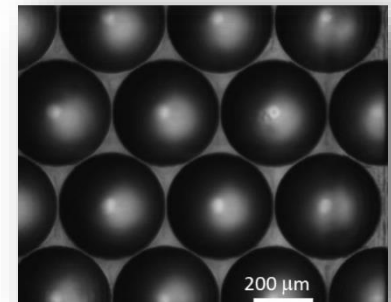
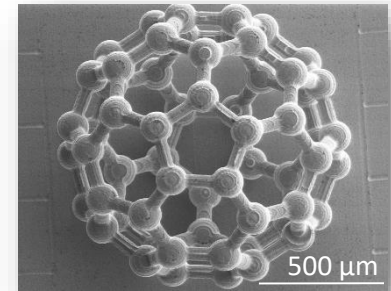
SURFACE QUALITY

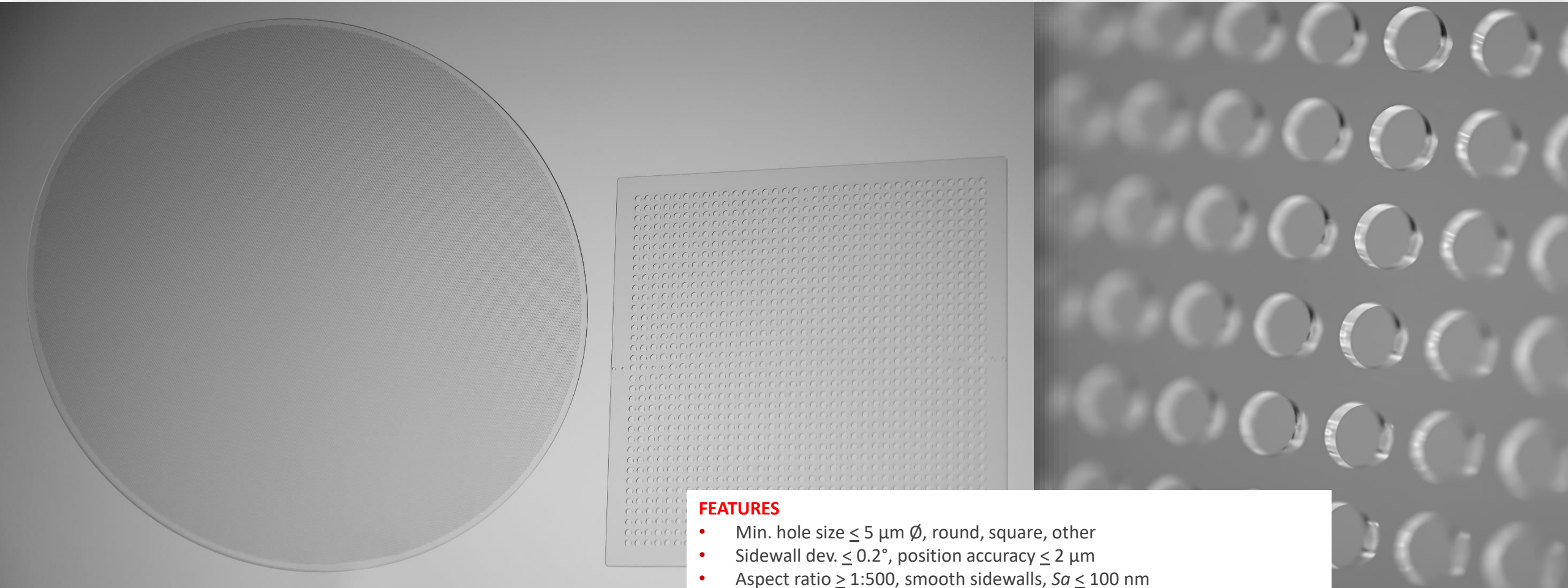
- Patterned surface $Sa \leq 100 \text{ nm}$
- Surface treatment $Sa \leq 10 \text{ nm}$

ASPECT RATIO

- Channel aspect ratio $\geq 1:500$
- Bulk height up to 30 mm
- Working area up to 300 mm \varnothing

*in SiO₂





- FEATURES**
- Min. hole size $\leq 5 \mu\text{m } \varnothing$, round, square, other
 - Sidewall dev. $\leq 0.2^\circ$, position accuracy $\leq 2 \mu\text{m}$
 - Aspect ratio $\geq 1:500$, smooth sidewalls, $Sa \leq 100 \text{ nm}$
 - Sharp or tapered edge, no sagging and chipping

01

TRANSPARENT AND ISOTROPIC

02

STABLE AND ELECTRICALLY INSULATING

03

BIOCOMPATIBLE

04

ELEVATED THERMAL PROPERTIES

05

HIGHLY ELASTIC

06

RESISTANT TO CORROSION, ABRASION AND SCRATCHES

07

NEUTRAL TO MAGNETIC FIELDS

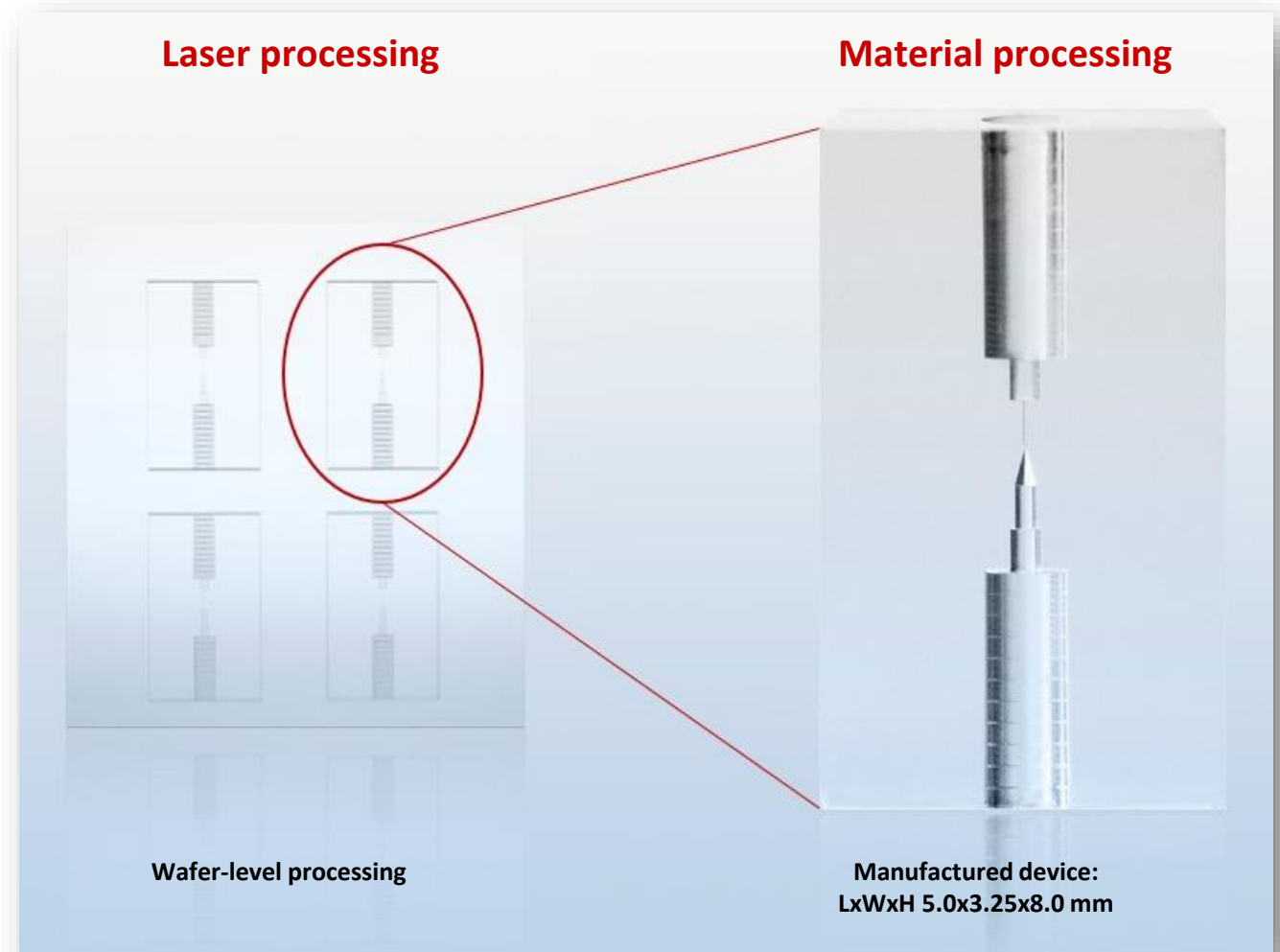


LASER 3D MICROFABRICATION

- laser-based microstructuring & material processing
- free-form 2D/3D microprocessing in glass materials

WHY WORKING WITH US

- In-house **unique know-how and capabilities** of glass micro-processing, from proof-of-concept, to pilot and series manufacturing;
- **Vertically integrated**, one-stop shop manufacturing foundry, delivering from single units up to volumes on wafer-level;
- Control over the **entire value chain** and **fast turnaround cycles** in prototyping;
- **ISO 13485:2016** certified for medical devices;
- Suitable for **numerous glass types**: fused silica, fused quartz, borosilicate, aluminosilicate, alkali-free, etc.



OPTO-MECHANICAL COMPONENTS

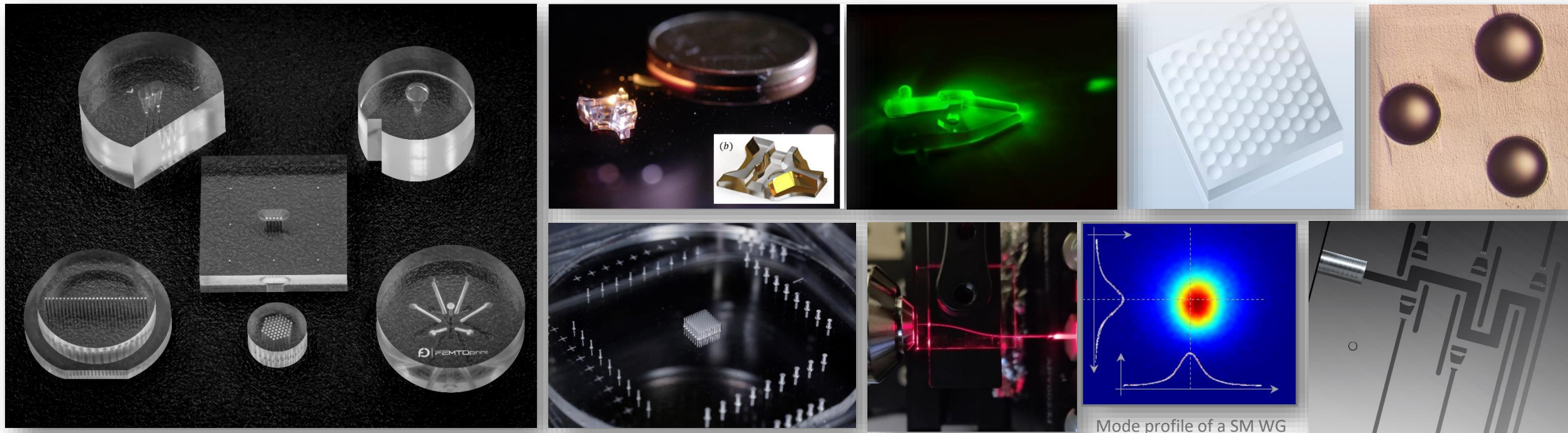
- Opto-mechanical aligners & positioners
- Interconnectors
- 3D v-grooves
- Fiber couplers
- Fiber-to-chip couplers
- Packaging & alignment elements

OPTICS & PHOTONICS COMPONENTS

- Diffractive elements
- Mini-/Micro-Prisms
- Mini-/Micro-Mirrors
- Waveguides
- Mini-/Micro-lenses
- Free-form mini-/micro-lenses
- Micro-lens arrays
- Masters & tooling

DEVICES & SYSTEMS

- Opto-mechanical sensing devices
- Opto-fluidic systems
- Lab-on-fibers

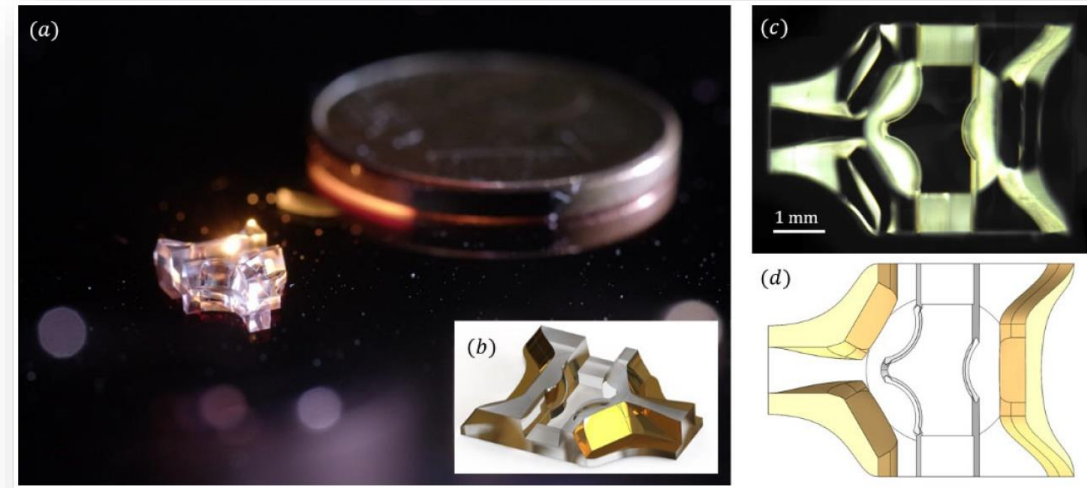


APPLICATION

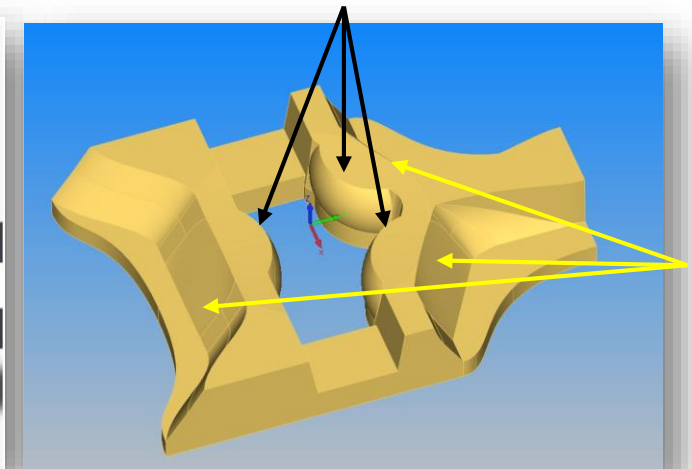
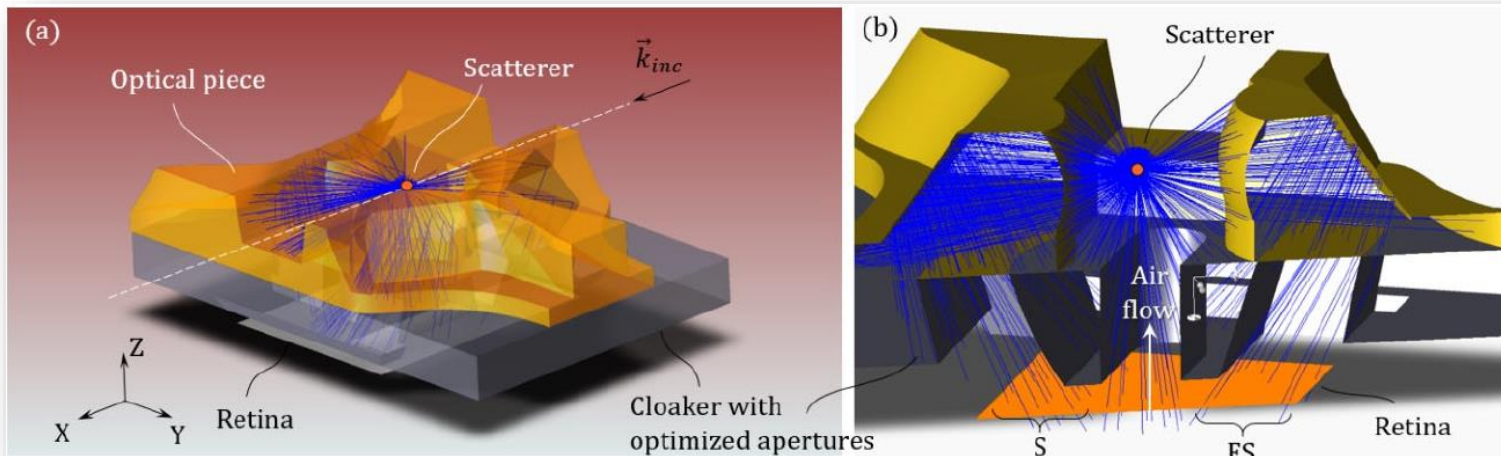
- Air quality monitoring
- Improved sensitivity by the integration of a miniaturized refractive/reflective optical system

USPs

- Integration of functionalities
- Free-form fabrication



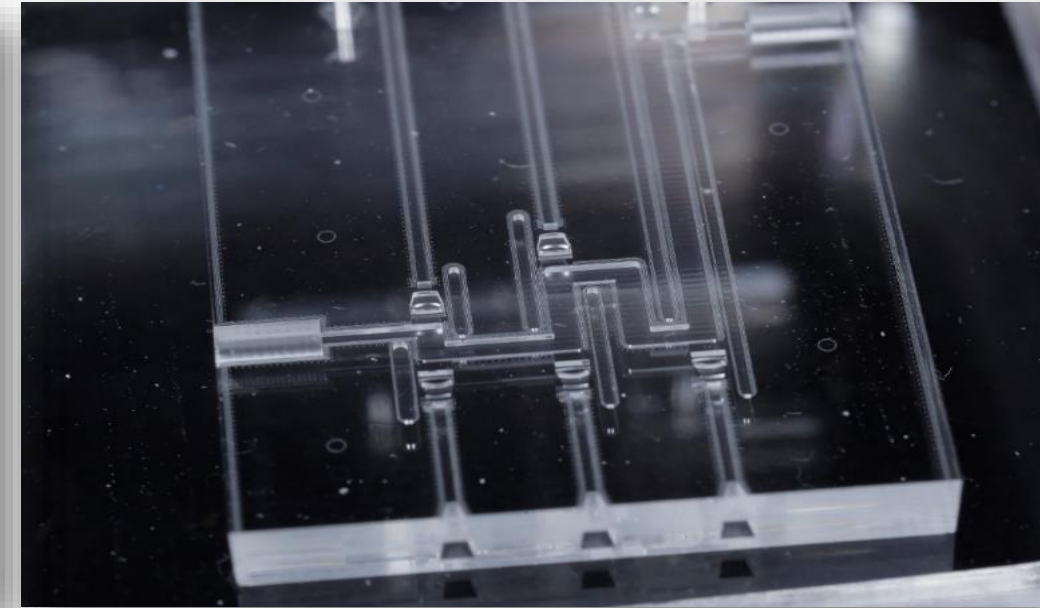
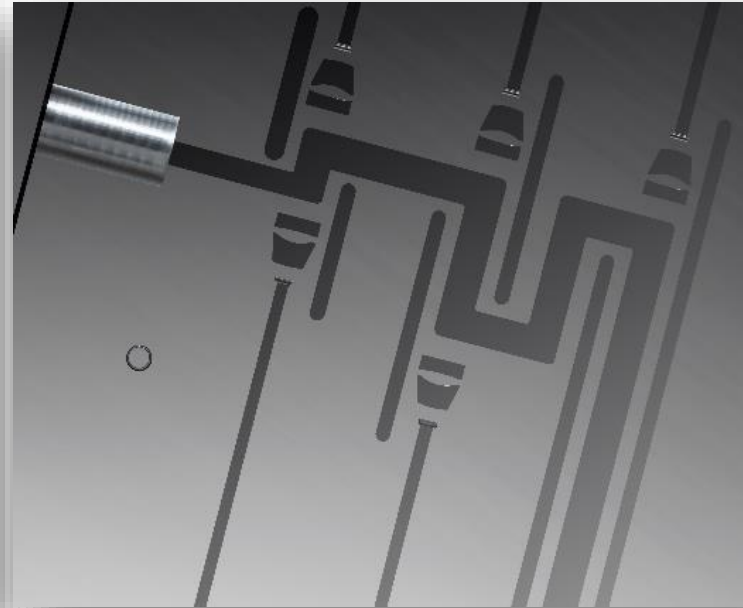
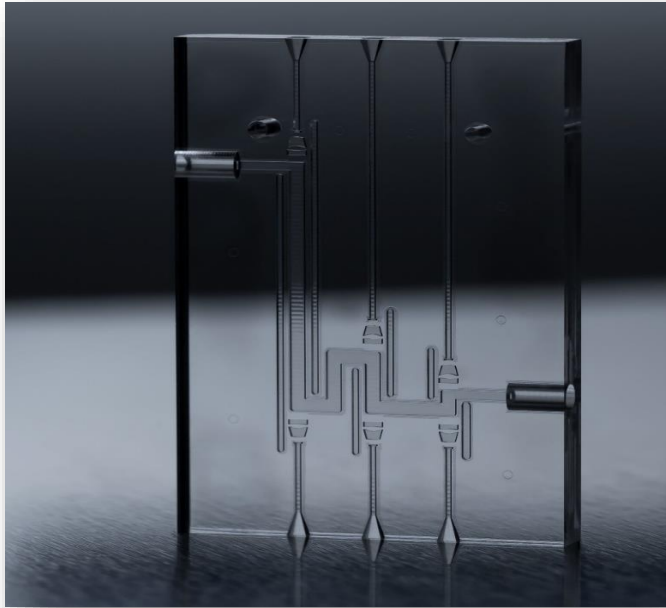
Freeform lenses



Freeform reflectors

CEA-LETI Minatec & Institut des Nanotechnologies de Lyon.

Jobert G. et al. Miniature Optical Particle Counter and Analyzer Involving a Fluidic-Optronic CMOS Chip Coupled with a Millimeter-Sized Glass Optical System. *Sensors* 2021, 21, 3181.



APPLICATION

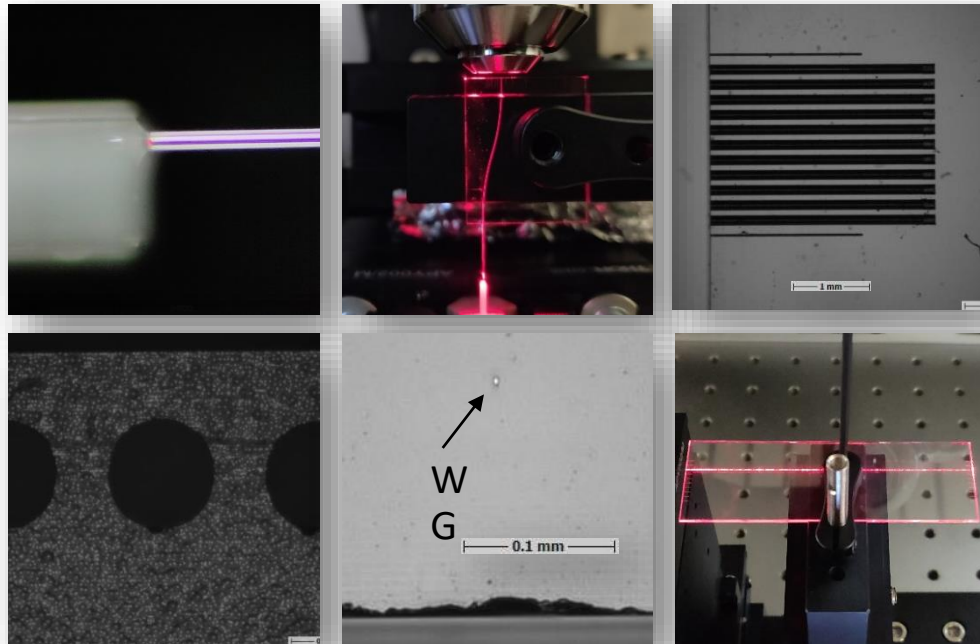
- Optofluidic Photonic Lab-on-a-Chip
- Monolithically integrated micro-optical system for the optical spectroscopy in a microfluidic structure

USPs

- Combination of functionalities
- Monolithic integration

CEA, DEN, DMRC, University of Montpellier, Marcoule, France.

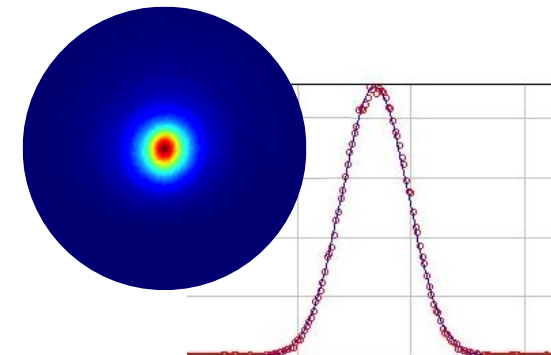
Elodie Mattio et al. Photonic Lab-on-a-Chip analytical systems for nuclear applications: optical performance and UV-Vis-IR material characterization after chemical exposure and gamma irradiation. Journal of Radioanalytical and Nuclear Chemistry (2020) 323:965–973.



ADDITIONAL FEATURES

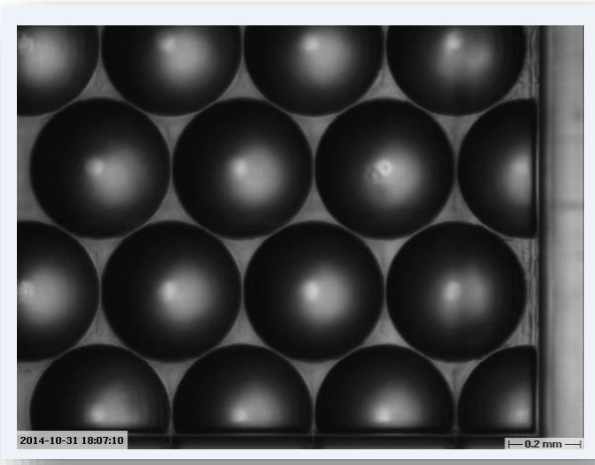
- **Alignment markers** and **grooves** can be conveniently added
- **Facet polishing** for rapid prototyping and characterization

Materials	FS, BF33, EXG
Working λ [nm]	630, 980, 1310, 1550
MFD SM [μm]	3 @ 630nm, 7 @ 980nm
Min. Curvature Radius	approx. 30mm
Propagation Loss	< 1 dB/cm
Δn	$10^{-2} - 10^{-3}$



SPHERICAL or ASPHERICAL

**MICRO-LENSES
&
MICRO-LENS ARRAYS**



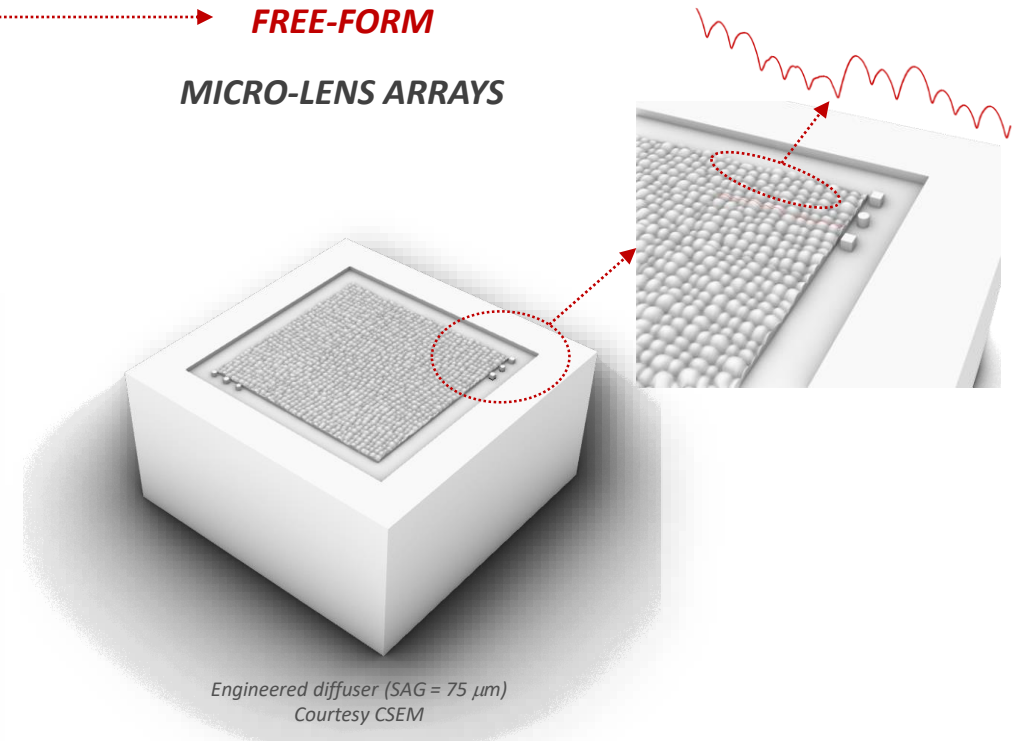
NON-SPHERICAL

MICRO-OPTICAL ELEMENTS



FREE-FORM

MICRO-LENS ARRAYS



Feasibility

Fast prototyping

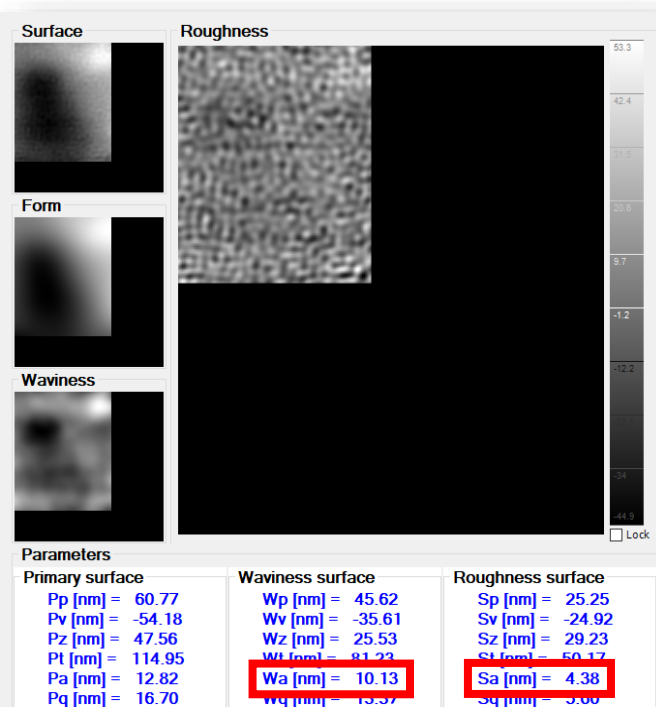
Pilot manufacturing

Small-to-medium volume
production

Origination & mastering
for large volume
production

Flat surfaces

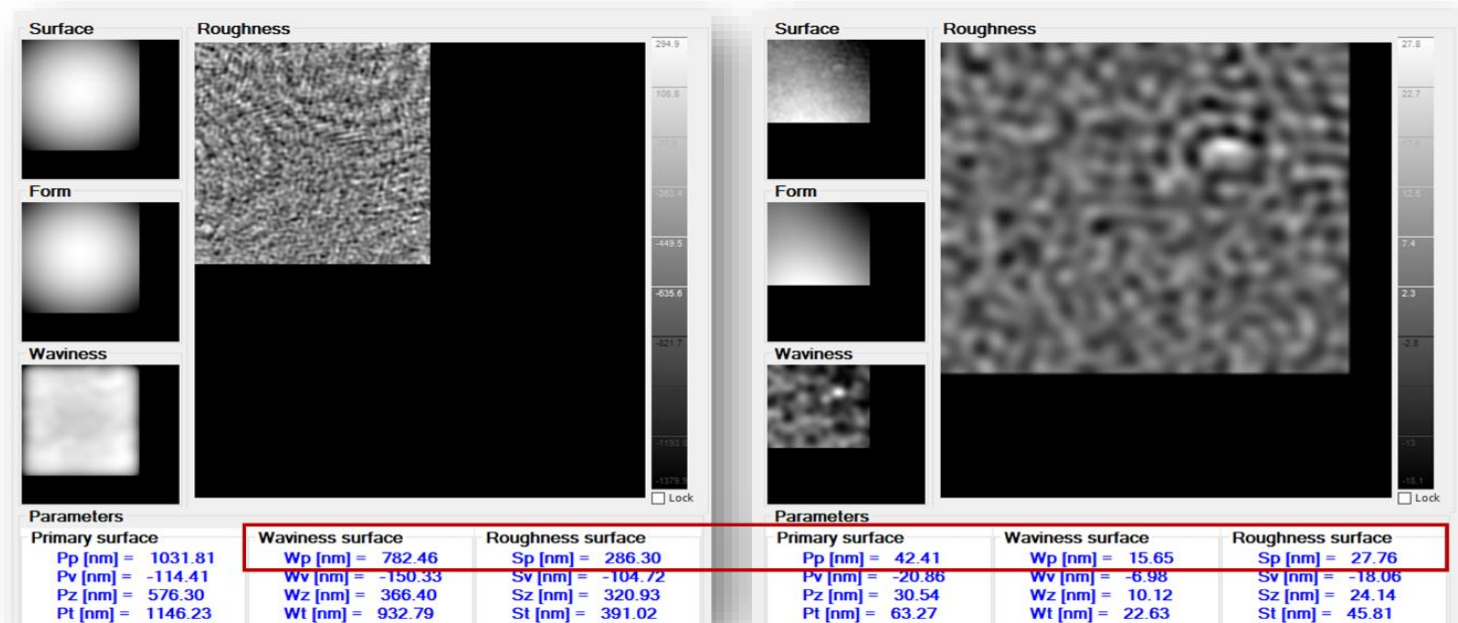
- $Sa < 10$ nm



Spherical / Aspherical Micro-lenses

(RoC = 125 μ m, SAG = 100 μ m)

- $Sa \leq 10$ -20 nm
- Shape accuracy ≤ 1 -3 μ m

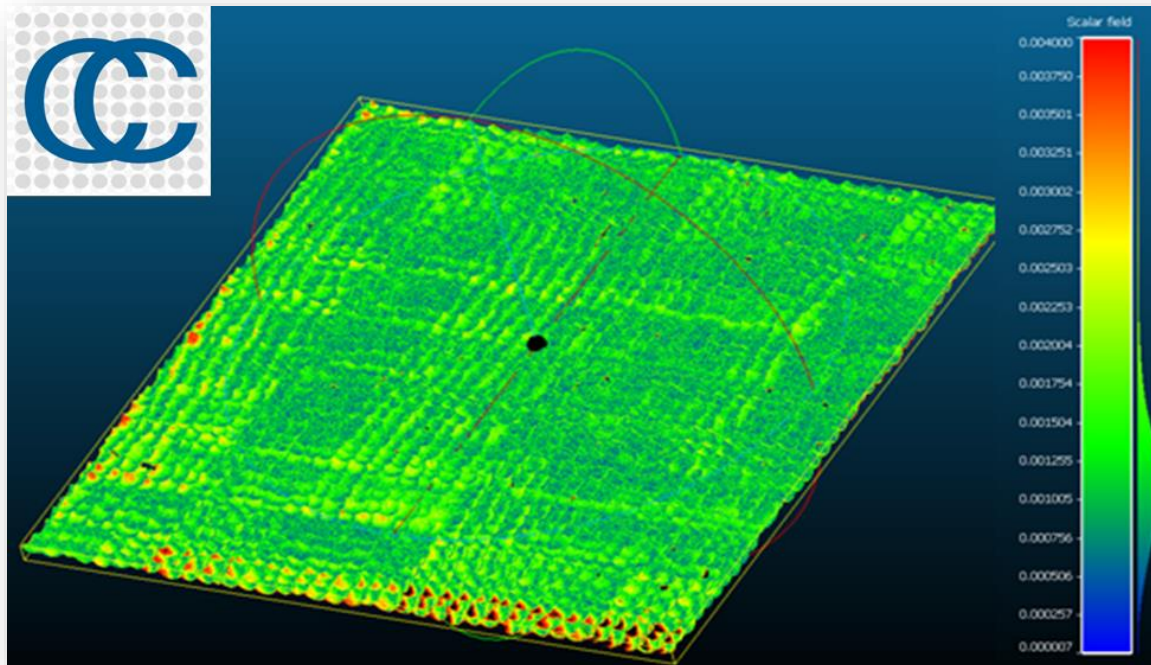


Innosuisse Project (n. 35418.1 IP-ENG)
Smart LASer Manufacturing for precision industry 4.0 (SLAM 4.0)

Free-form Micro-lenses

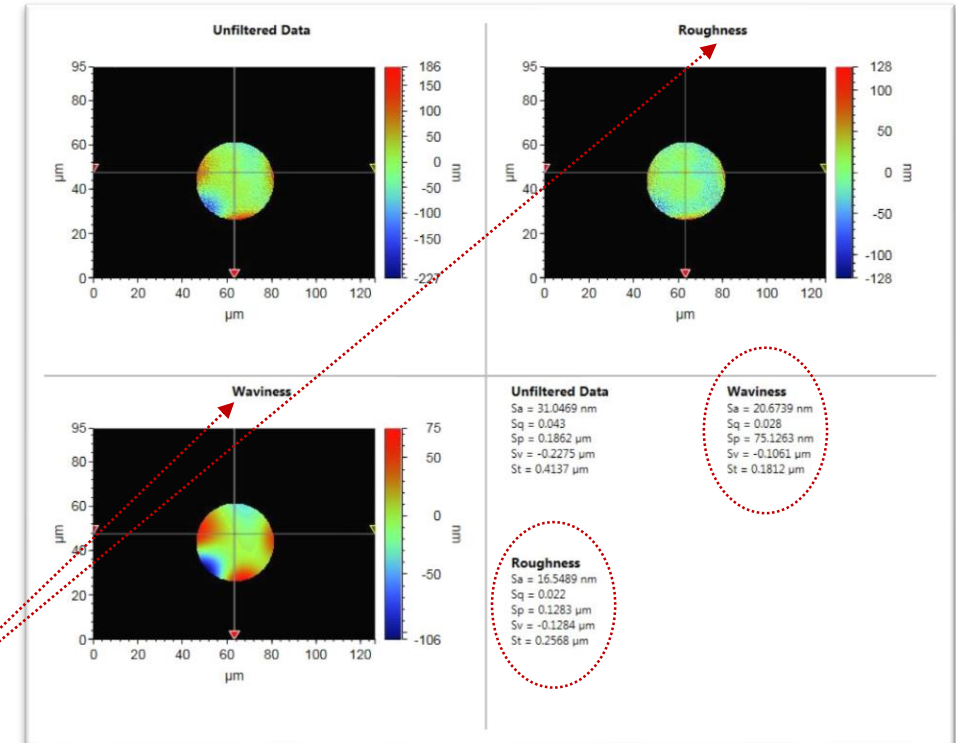
(SAG = 75 μm)

- $Sa \leq 20$ nm
- Shape accuracy $\leq 2-3$ μm



Nominal design vs measured surface – Cloud Compare

Courtesy of CSEM



Innosuisse Project (n. 35418.1 IP-ENG)
Smart LAsER Manufacturing for precision industry 4.0 (SLAM 4.0)

WHAT CAN WE DO FOR YOU?

- 3D printing of glass miniaturized & micro- optical components, devices, and systems
- From free-form 2.5D micro-optical elements to 3D miniaturized optical systems
- From feasibility & fast prototyping to pilot manufacturing & volume production
- Origination, Mastering & Tooling for large volume replication (UV imprint, hot embossing, injection molding)
- Monolithically integrated photonic systems, incl. fiber-to-chip coupling solutions for PICs & 3D waveguides

WHAT CAN YOU DO FOR US?

- Metrology ... metrology ... and metrology !!!
- Requests for fast-prototyping, pilot manufacturing, and mastering/tooling services
- Collaboration on the development & manufacturing of miniaturized & micro- optical components, devices, and systems
- Collaboration on the development & manufacturing of application specific photonic systems
- Collaboration on uses cases, where several optical & non-optical functionalities are combined in glass micro-devices

Thank
you!



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