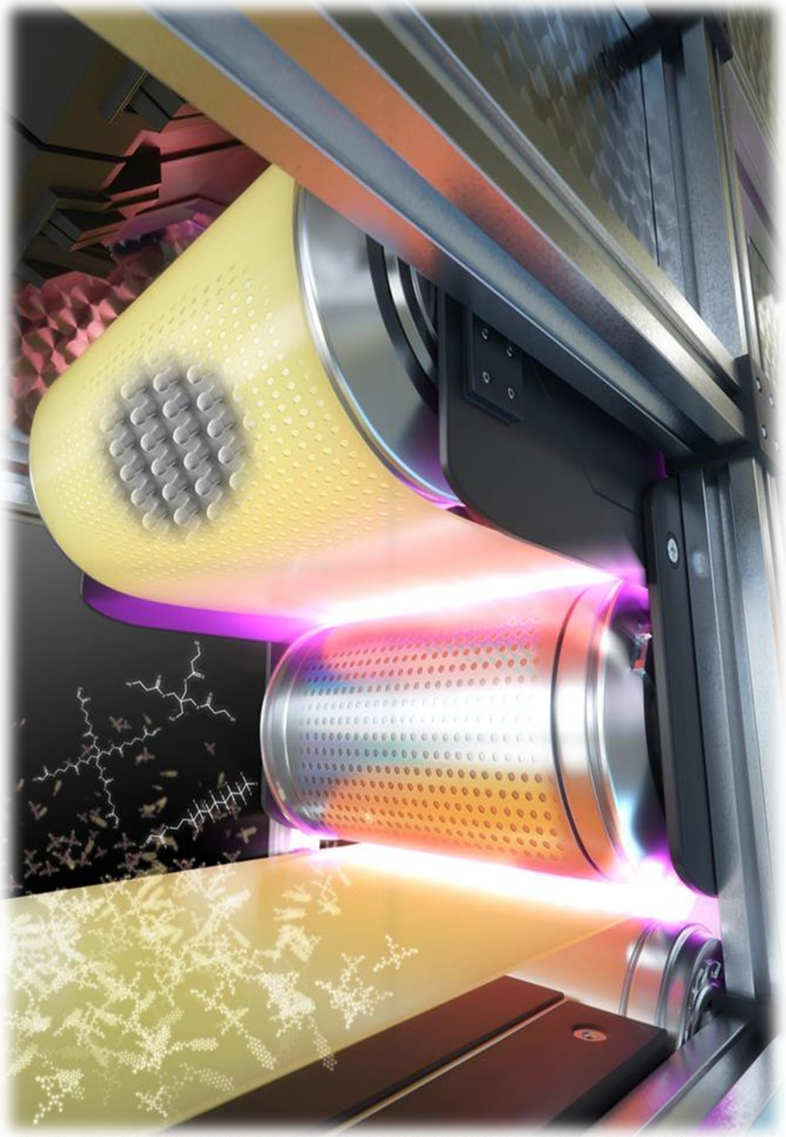


Roll-2-Roll imprinting solutions in lighting

Recent progress in UV-Nanoimprinting of Micro Optics on Foil

Paul Hartmann

JOANNEUM RESEARCH

MATERIALS

Institute for Sensors, Photonics and Manufacturing Technologies

Amsterdam, December 2nd, 2024

MATERIALS
Institute for Sensors, Photonics and Manufacturing Technologies

- Director:
  - Paul Hartmann
- 5 Research Groups
  ~ 100 Employees
- 2 Locations in Styria
  - Weiz
  - Niklasdorf
- 1 Location in Burgenland
  - Pinkafeld

Hybrid Electronics and Patterning
Barbara Stadlober

Light and Optical Technologies
Christian Sommer

Laser and Plasma Processing
Wolfgang Waldhauser

Sensors and Functional Printing
Jan Hesse

Smart Connected Lighting
Andreas Weiss

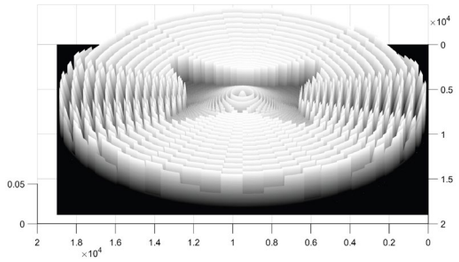
Roll-2-Roll UV-NIL Pilot Line
an optimized value chain for micro-optics

MATERIAL

NILcure

e.g. Poly-Urethane-Acrylates

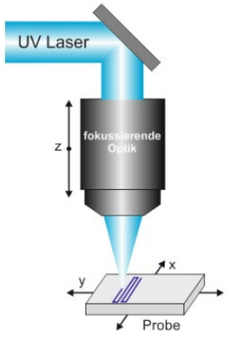
SIMULATION & DESIGN



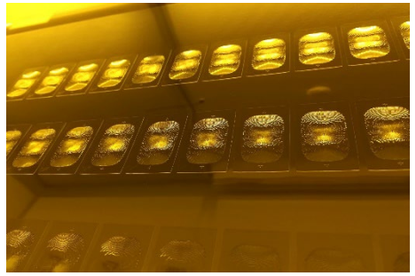
e.g. COMSOL, Ray Tracing

MASTER

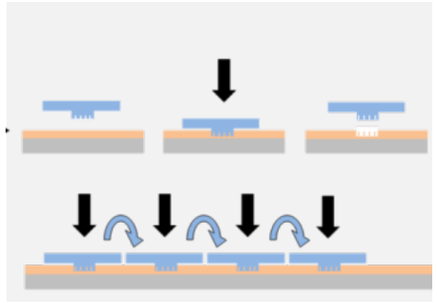
e.g. Maskless Laser Lithography



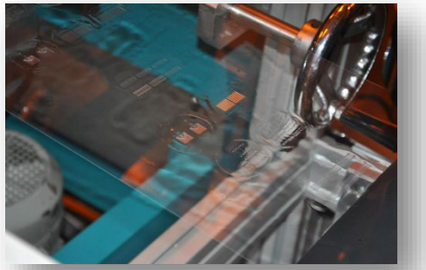
STAMP / SHIM



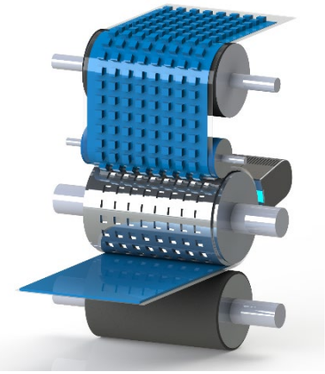
Step & Repeat UV-NIL



PRODUCTION



R2R-UV-NIL



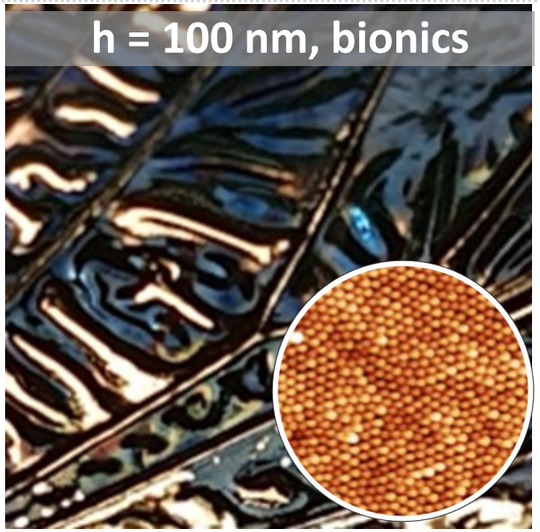
MICRO-OPTICS IS...

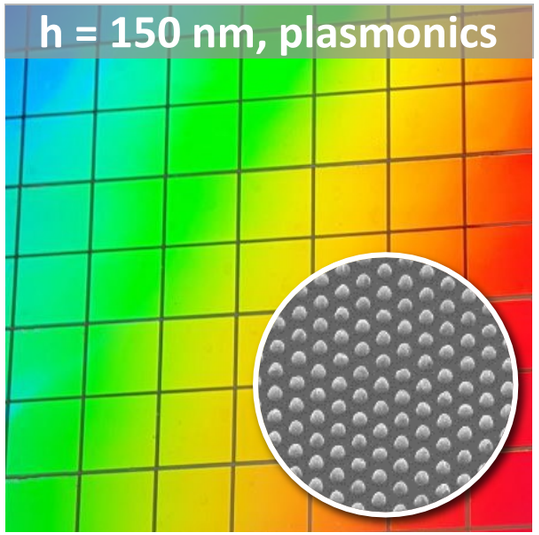
Phabulops

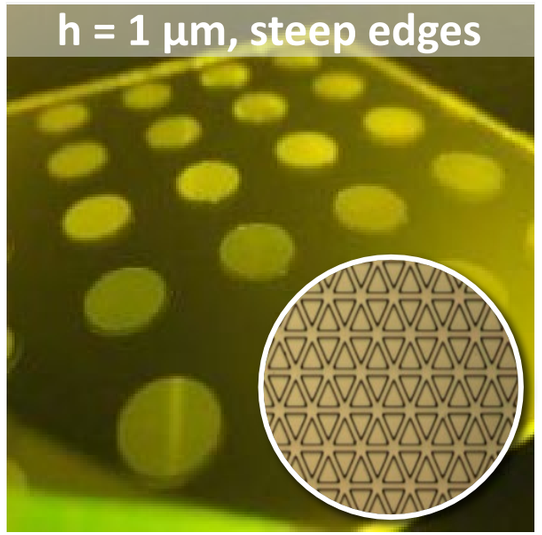
UPSCALING

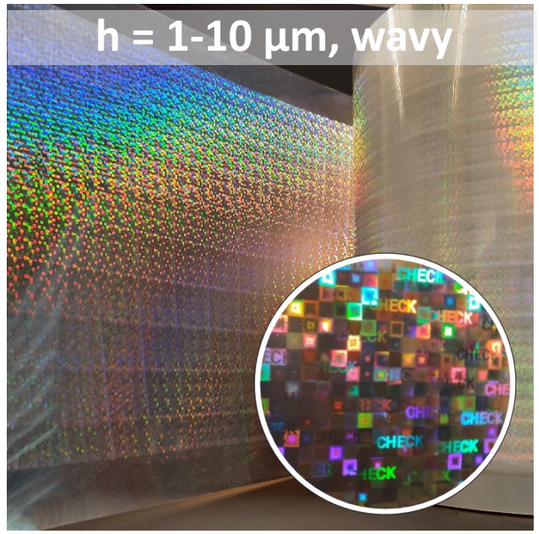
Application examples of nano and micro imprinting

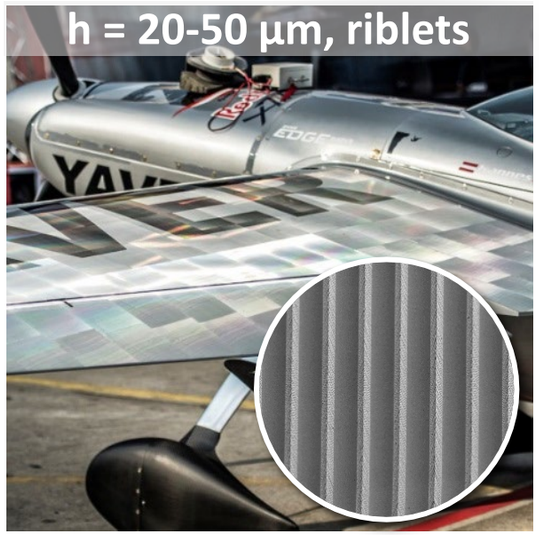
Structures range from 100nm to 200µm

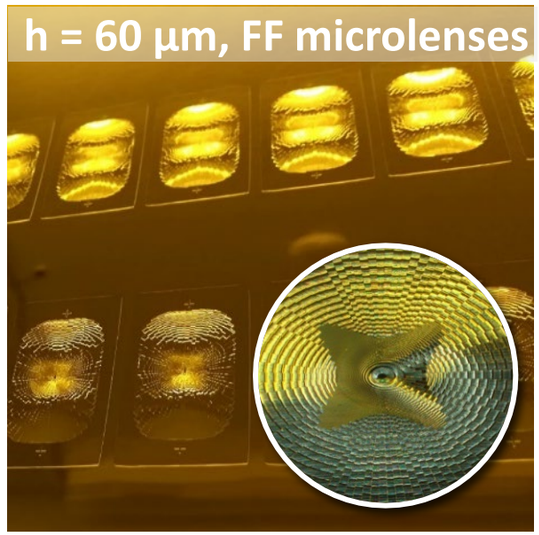


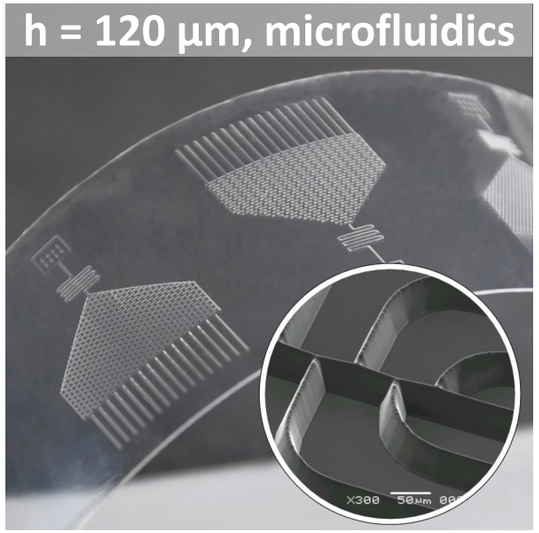


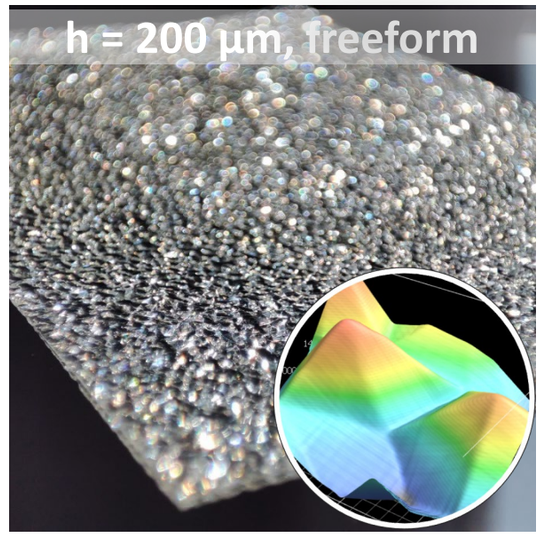








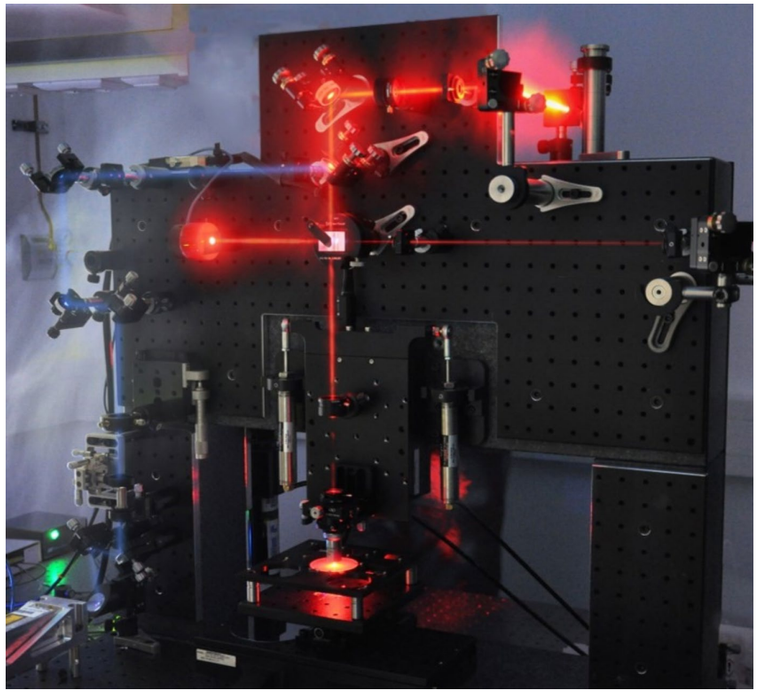


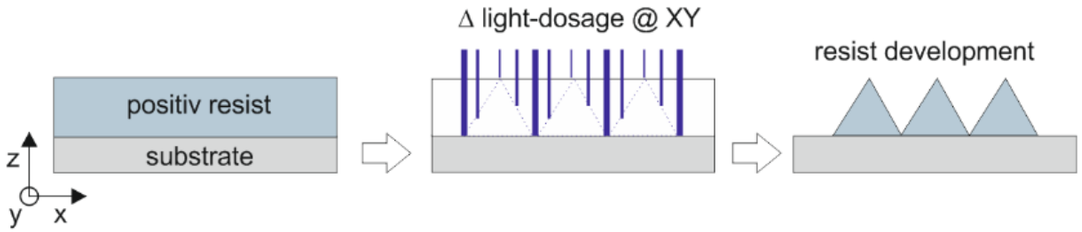


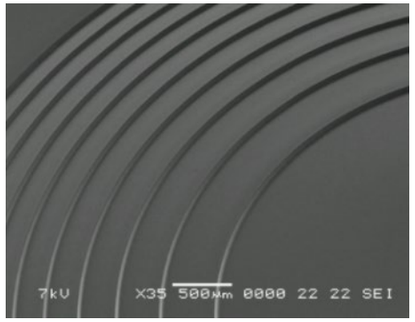
Mastering: Grey Scale Lithography

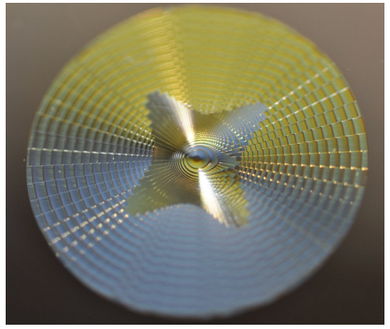
Main features (Status 2024)

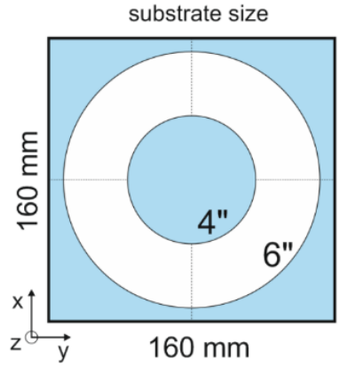
- Structuring on planar and curved substrates
- Min. feature size(XY): 200 nm
- Max. structure height(Z): 60 µm
- Aspect ratio: 4:1
- Structure type: 1D, 2D, 2.5D and free-form
- Writing speed (CD = 1 µm) 1 cm^2/h
- Max. area 16 x 16 cm² (6” x 6”)







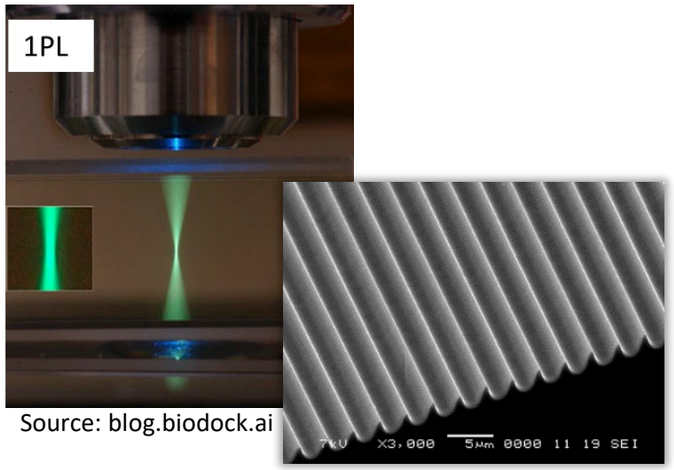




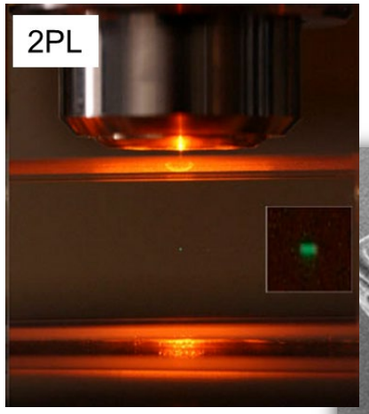
Ongoing Developments in Laser Lithography

Integration of different laser lithography technologies, quality monitoring systems and processes in **one platform** for the development of **structures with high depth** (from **100 nm** to **sub-mm)**, **2D & 3D shapes** on flat surface, combining **parallel & serial patterning** for increased speed and large area (up to 2000cm²)

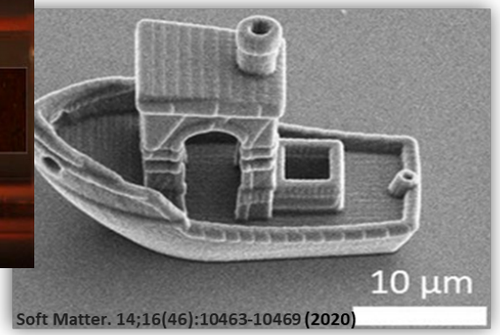
One-Photon Lithography (1PL) **+** **Two-Photon Lithography (2PL)** **+** **Laser Interference Lithography (LIL)**

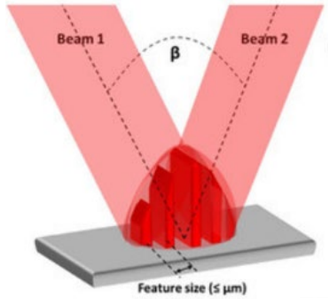


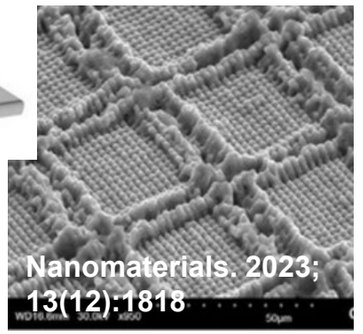
Source: blog.biodock.ai



Source: blog.biodock.ai

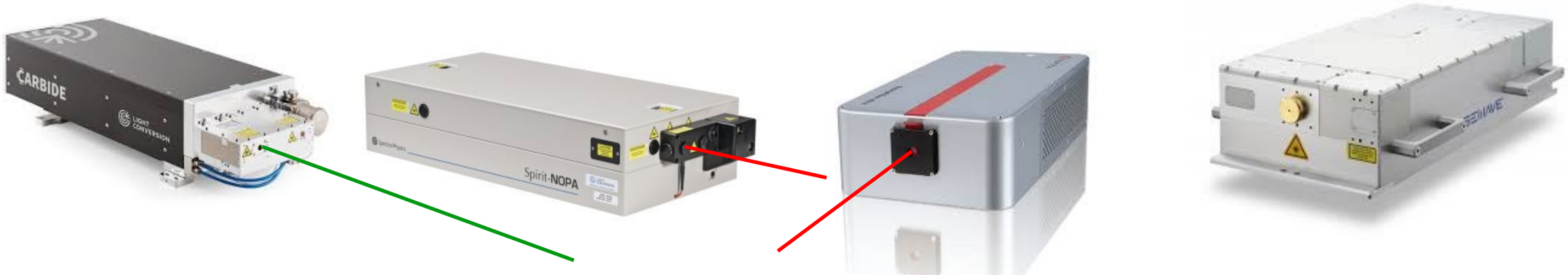




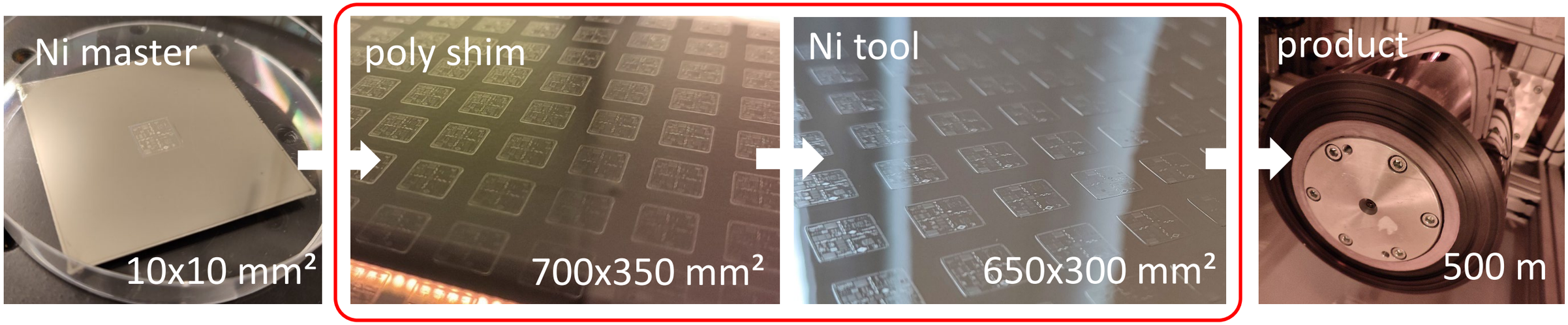


Laser Micromachining at JR MATERIALS

- Modern ultrashort pulse (USP) laser labs
  - Light Conversion Carbide fs-Laser
  - Spectra Physics Spirit fs-Lasers
  - Toptica fs-Laser
  - Edgewave ps-Laser
  - Trumpf ns-Laser
- High-precision xy-stages
- Galvoscanners (synchr.)
  - Working range: max. 210 mm × 210 mm
- Cleanroom Class 6, ISO 14644



Large-area tooling is still a bottleneck

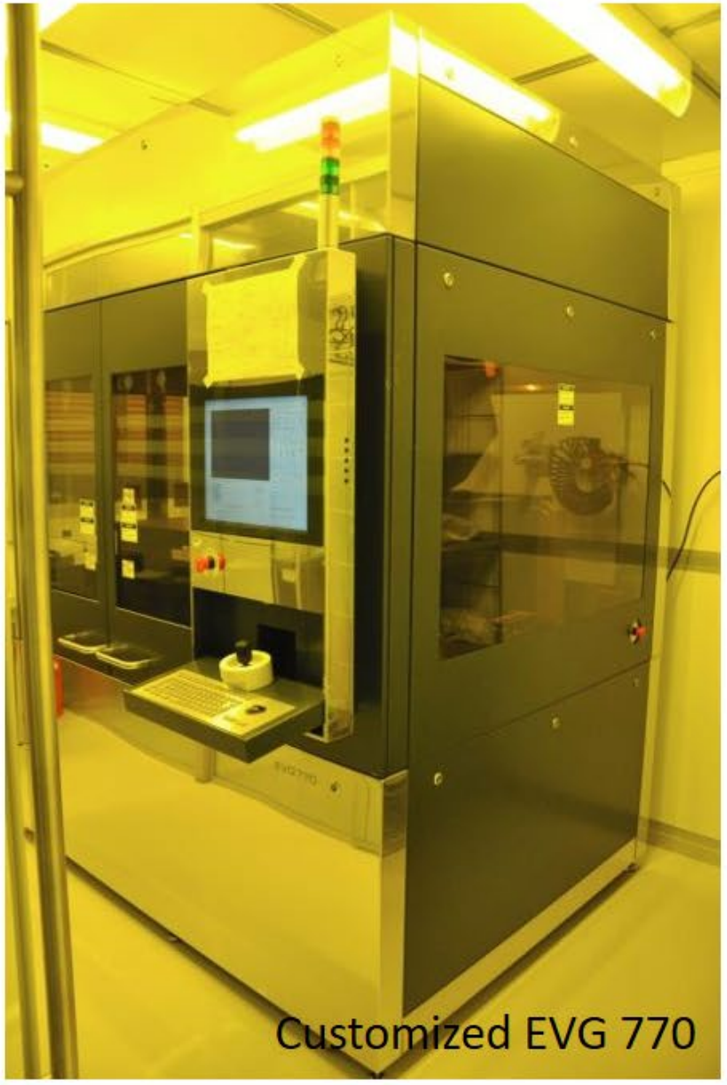


Typical active area from origination (for freeform, nano, high AR, hierarchical…):
10 x 10 mm² – 30 x 30 mm²

Typical master materials:
resin, Ni, Si, quartz, silicones,…

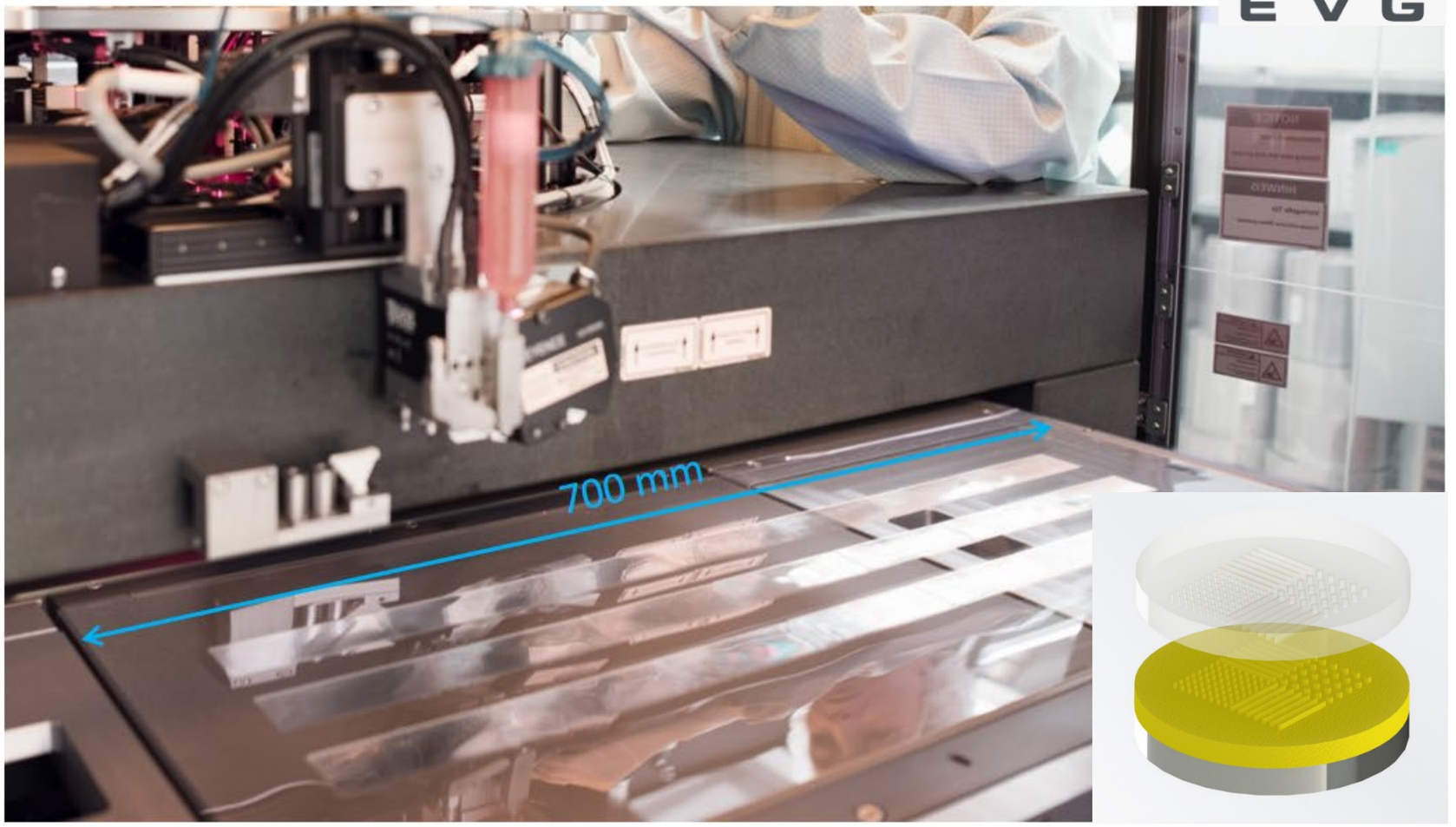
We need **powerful, flexible and highly accurate** upscaling and tooling processes.

Step & Repeat upscaling @JR

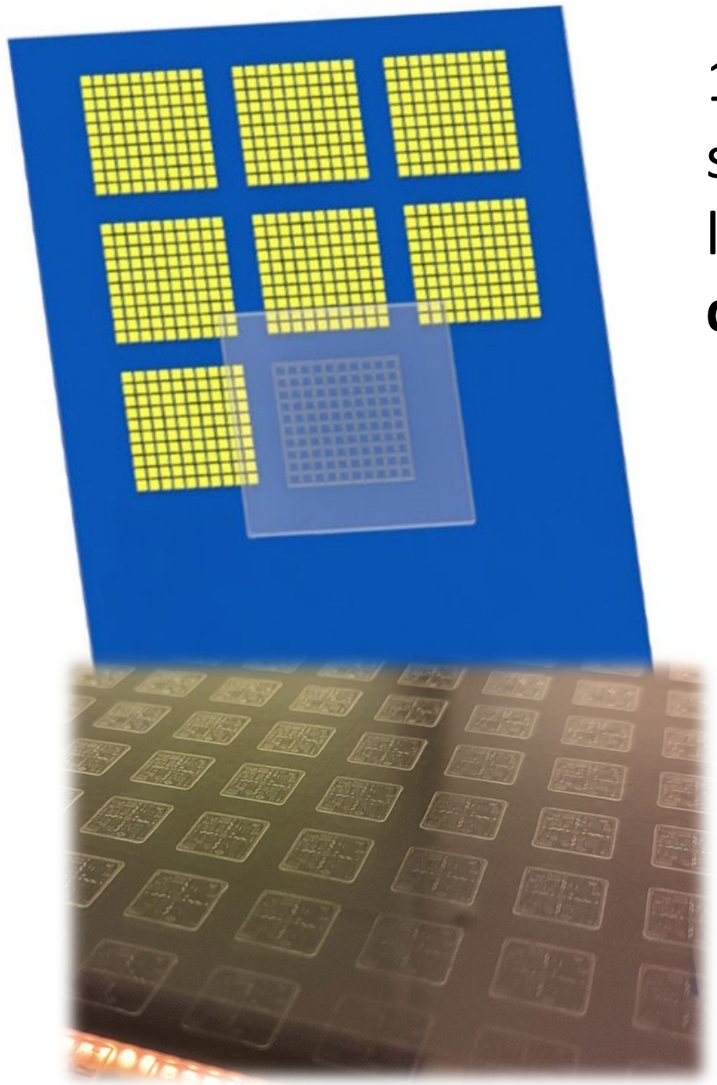


Max. substrate area: 700 x 380 mm²
(Tool size for R2R@JR: 630 x 270 mm²)

Stage positioning accuracy: ~3 µm
Overlay alignment accuracy: <1 µm

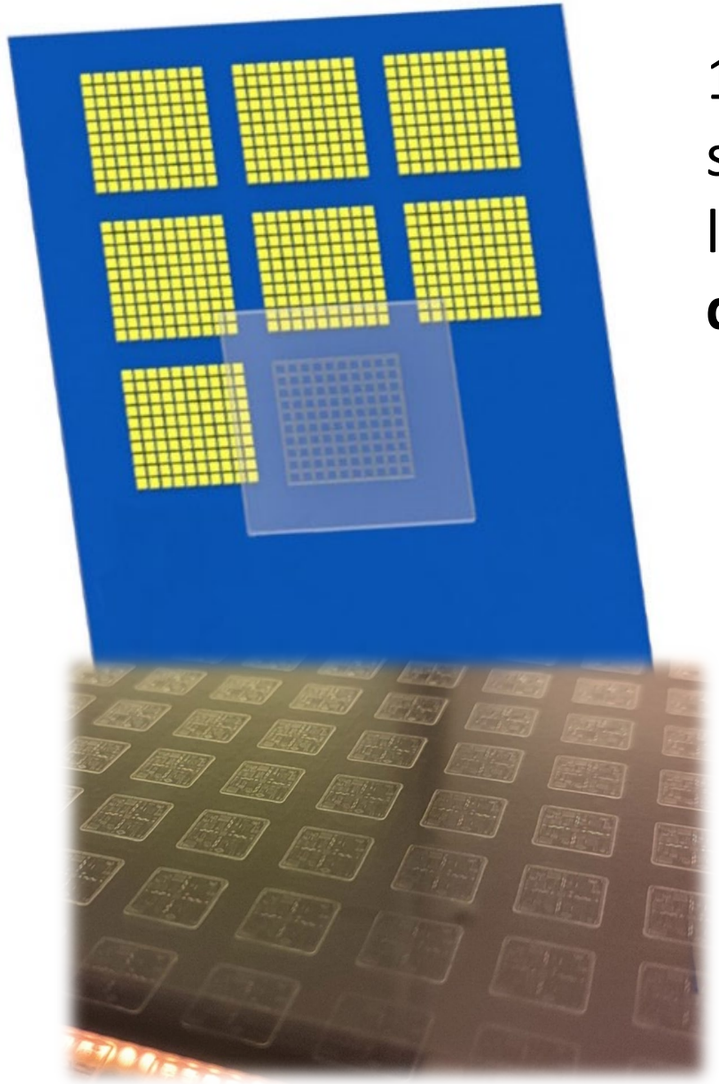


Step & Repeat UV-NIL Upscaling From master to poly-shim

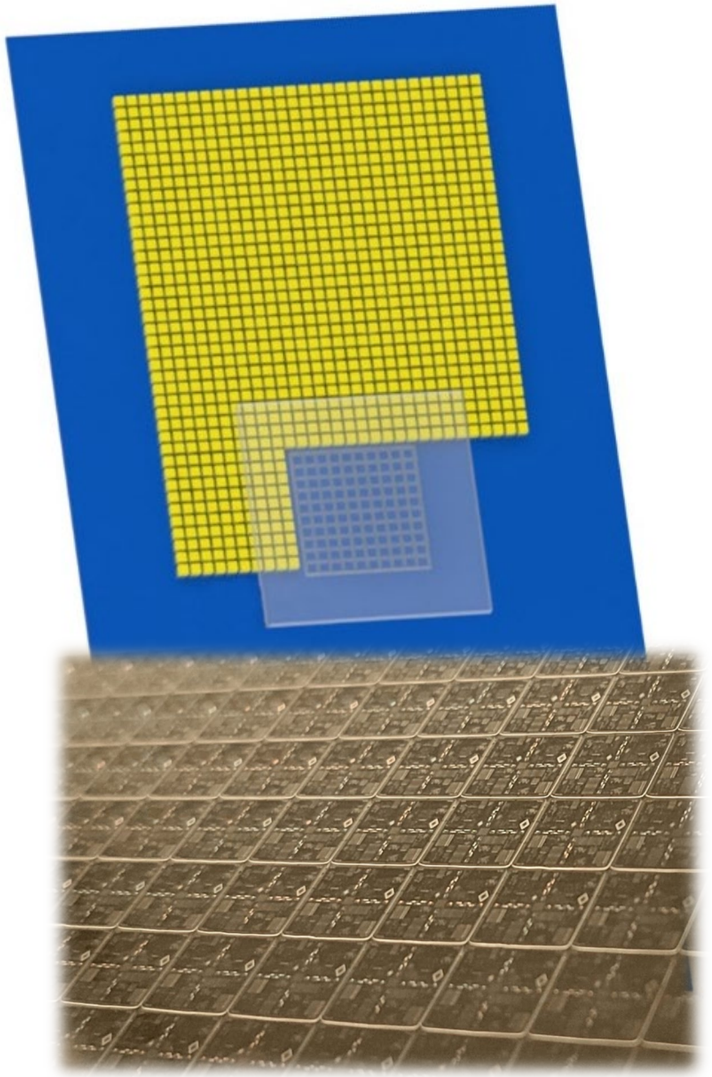


1) Multiple replication of a small master field on a larger area **with given distance** to each other

Step & Repeat UV-NIL Upscaling From master to poly-shim

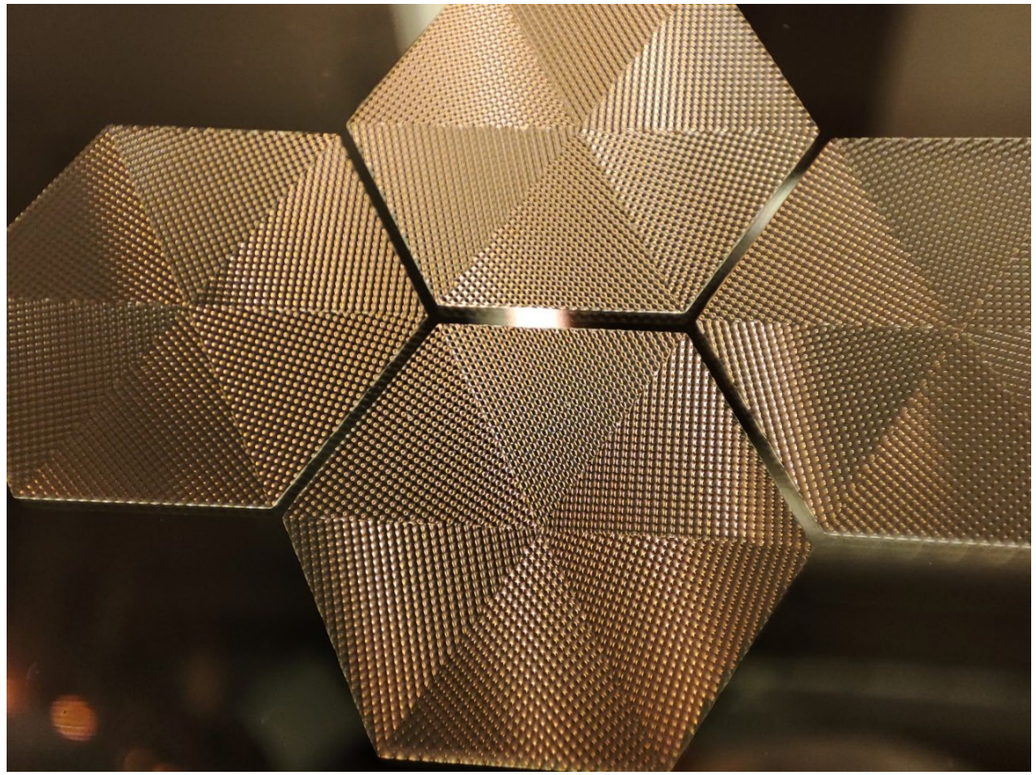


1) Multiple replication of a small master field on a larger area **with given distance** to each other



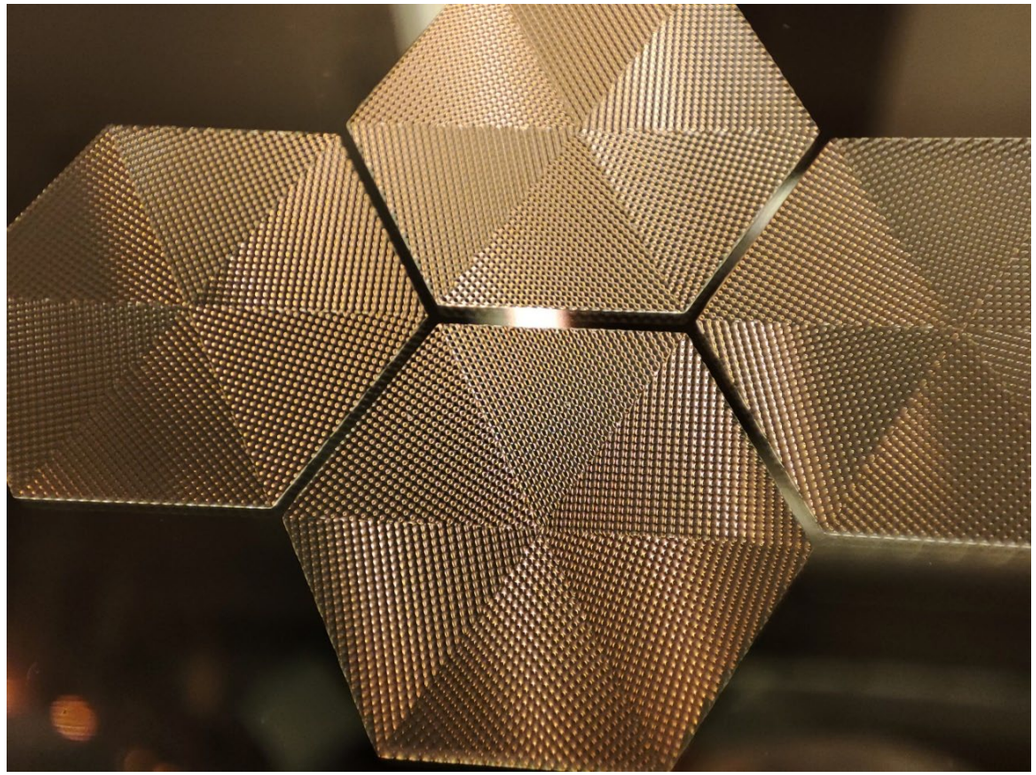
2) Multiple replication of a small master field **with minimum distance** to each other or **„seamless“**

Seamless Step & Repeat Upscaling



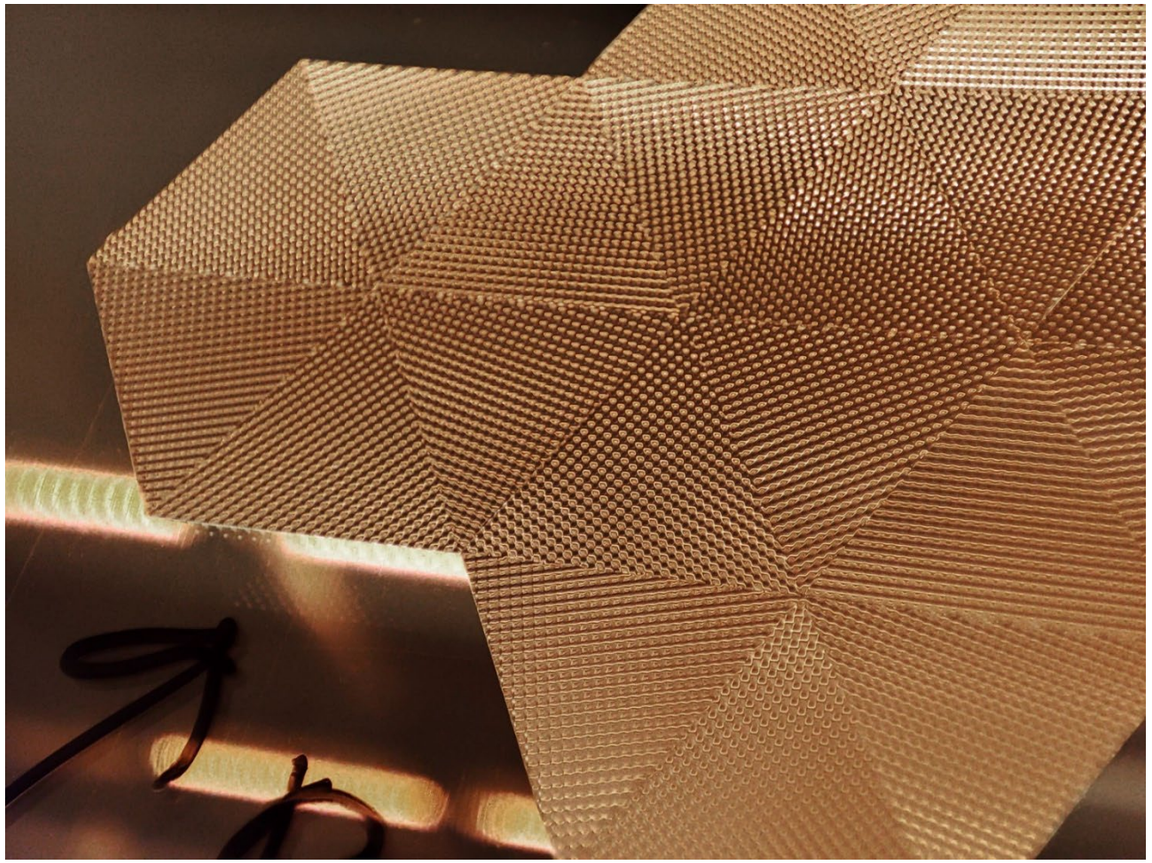
Step&Repeat UV imprints on PET foil
distance = 1 mm

Seamless Step & Repeat Upscaling



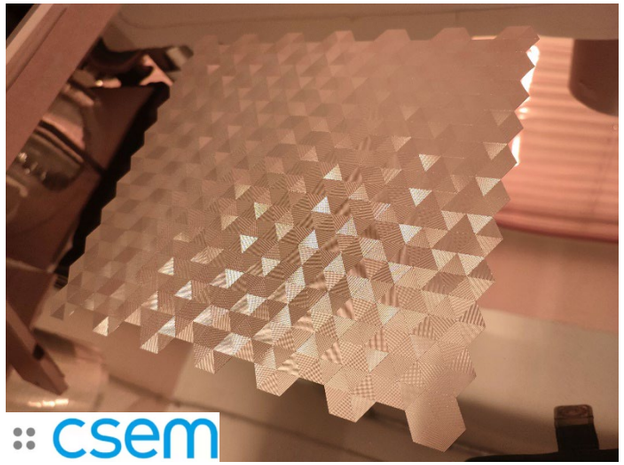
Step&Repeat UV imprints on PET foil
distance = 1 mm

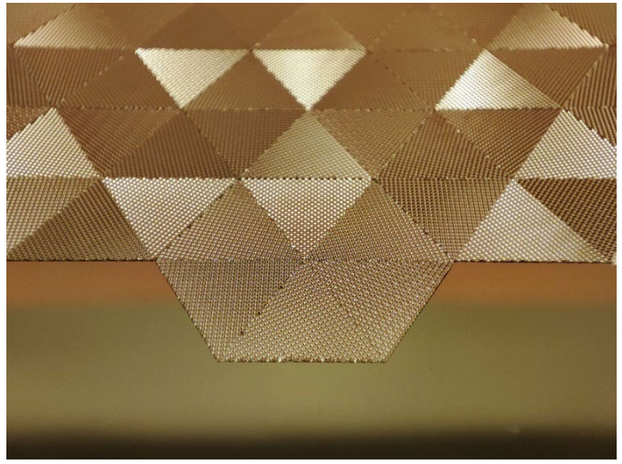
Distance and
rotation optimization

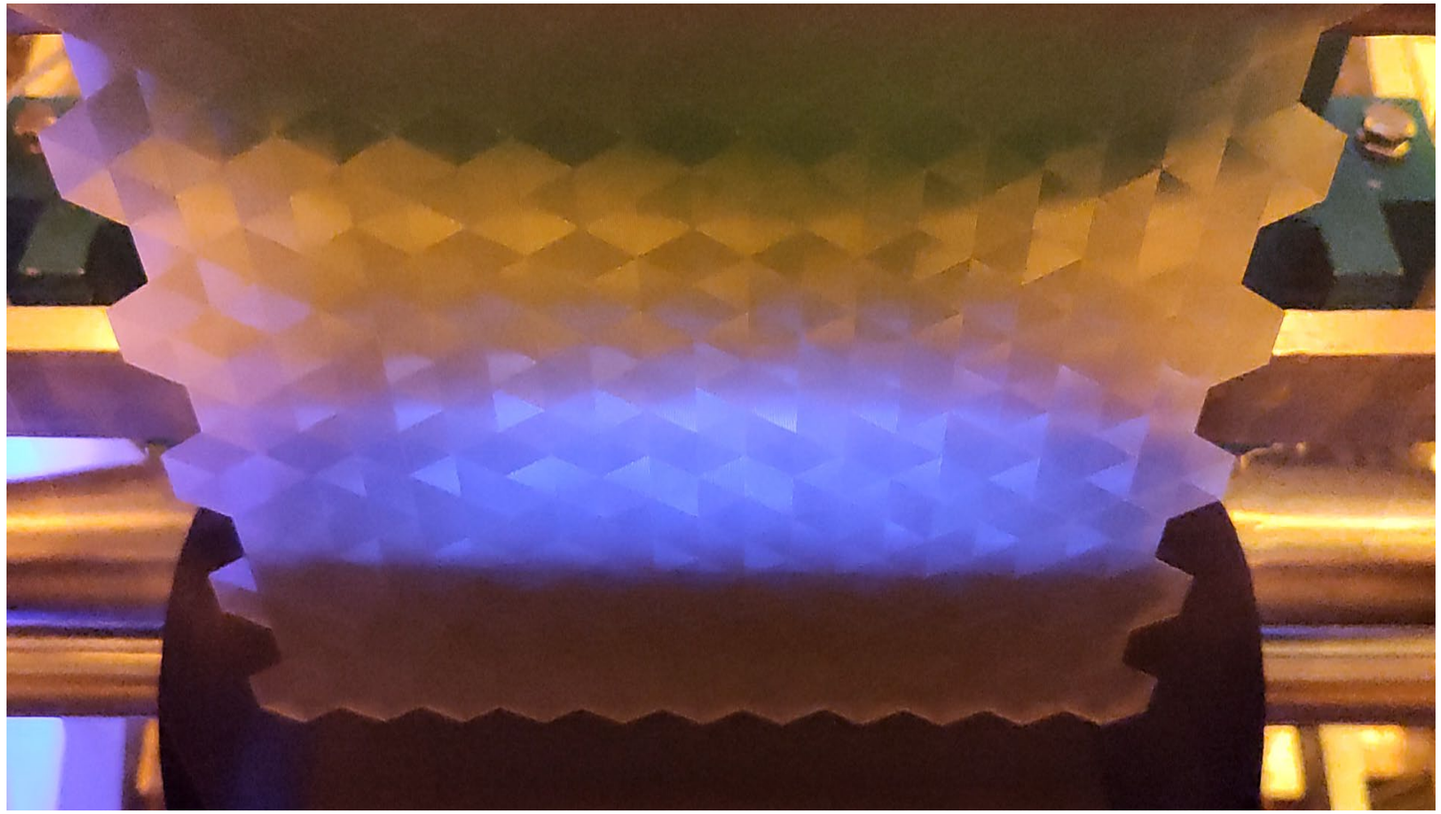


Roll-to-Roll (R2R) replication

Converting the poly-shim
to a durable Ni tool







Use Case 1: Decorative Films

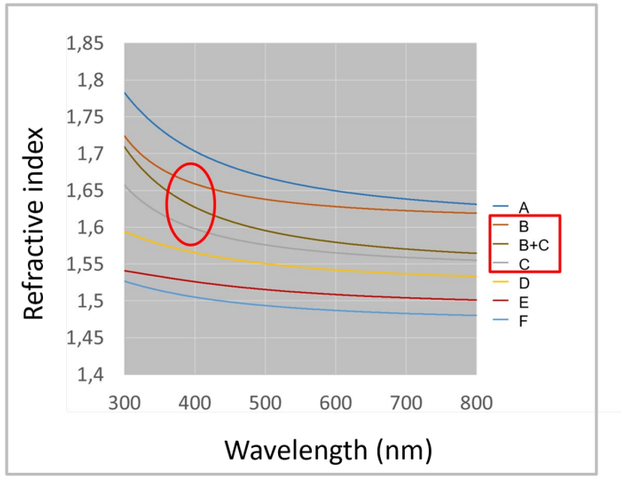
Application:

Freeform micro-facets to realize a sparkling effect for luxury goods

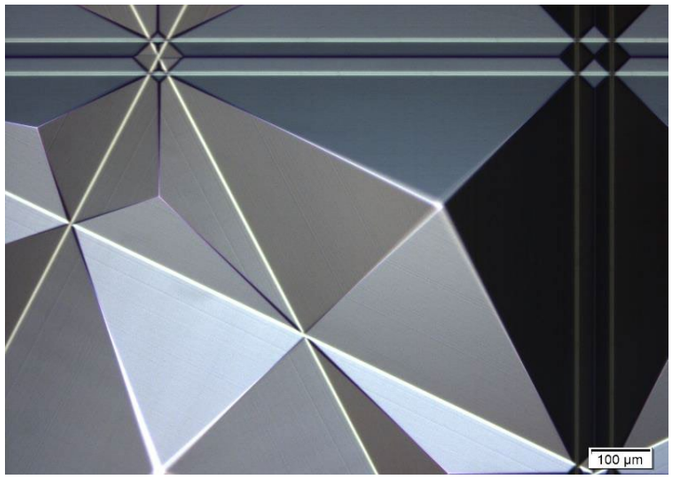
Upscaling target: Seamless Step & Repeat Upscaling for Roll-to-Roll production

Seamless stitching of distributed facets with extremely high edge accuracy, low shrinking and low Abbe number

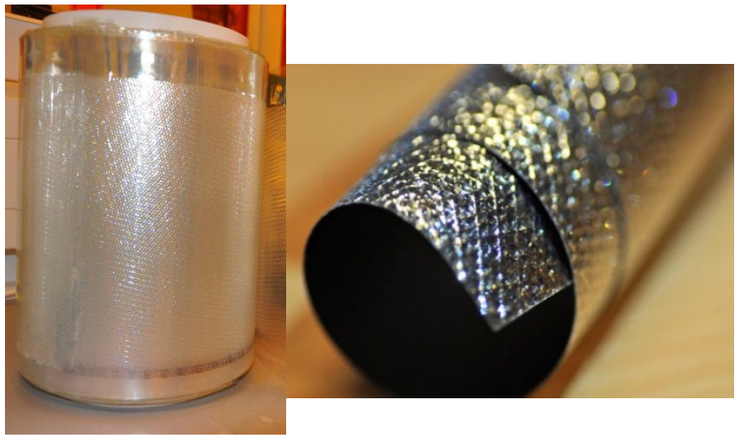
Resin with high dispersion



„Crystals“ with facet designs

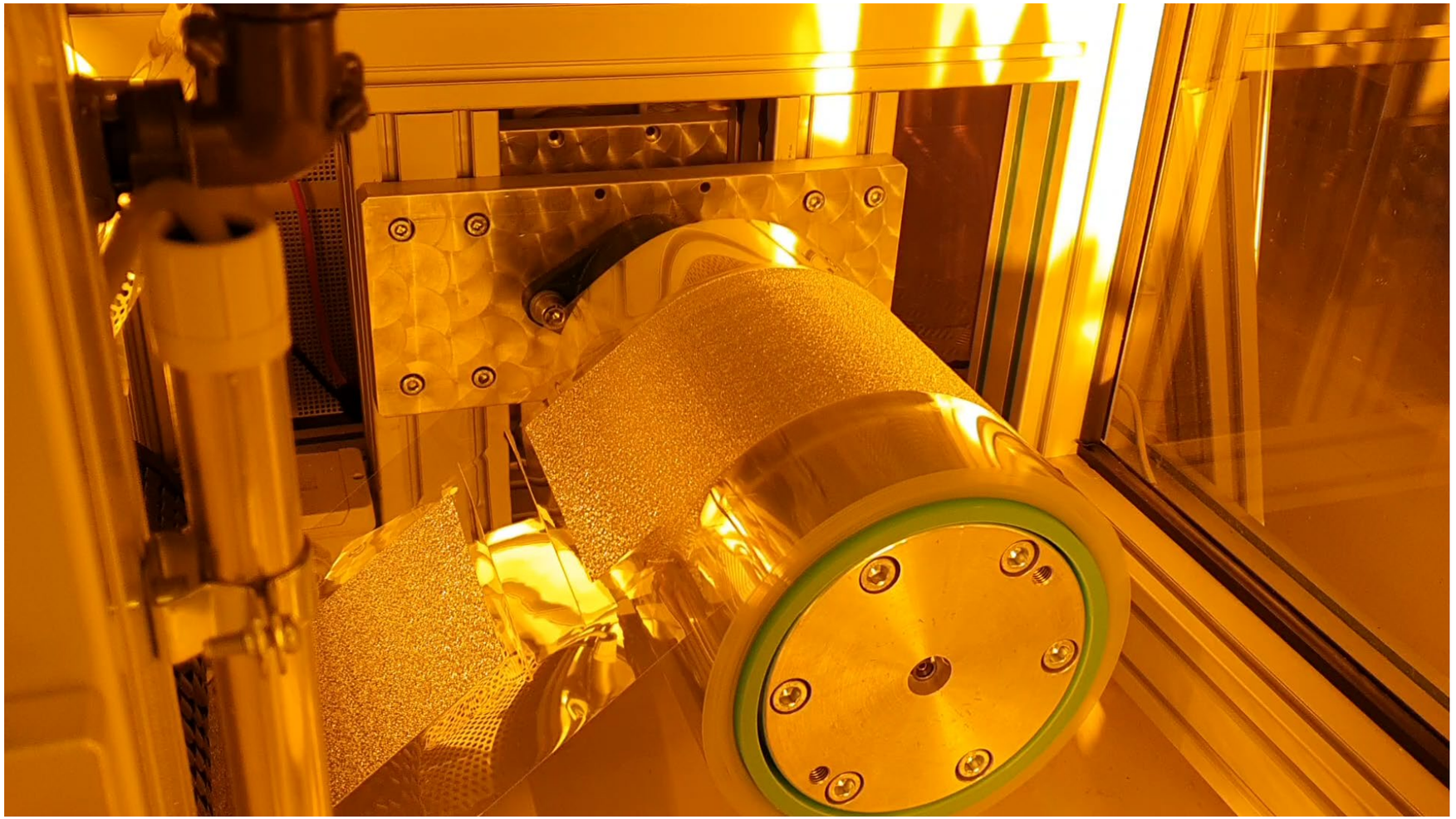


Double side imprinted „crystals“



Roll-to-roll (R2R) replication of facets
with high accuracy of replication

R2R UV imprint into high index, high dispersion resin



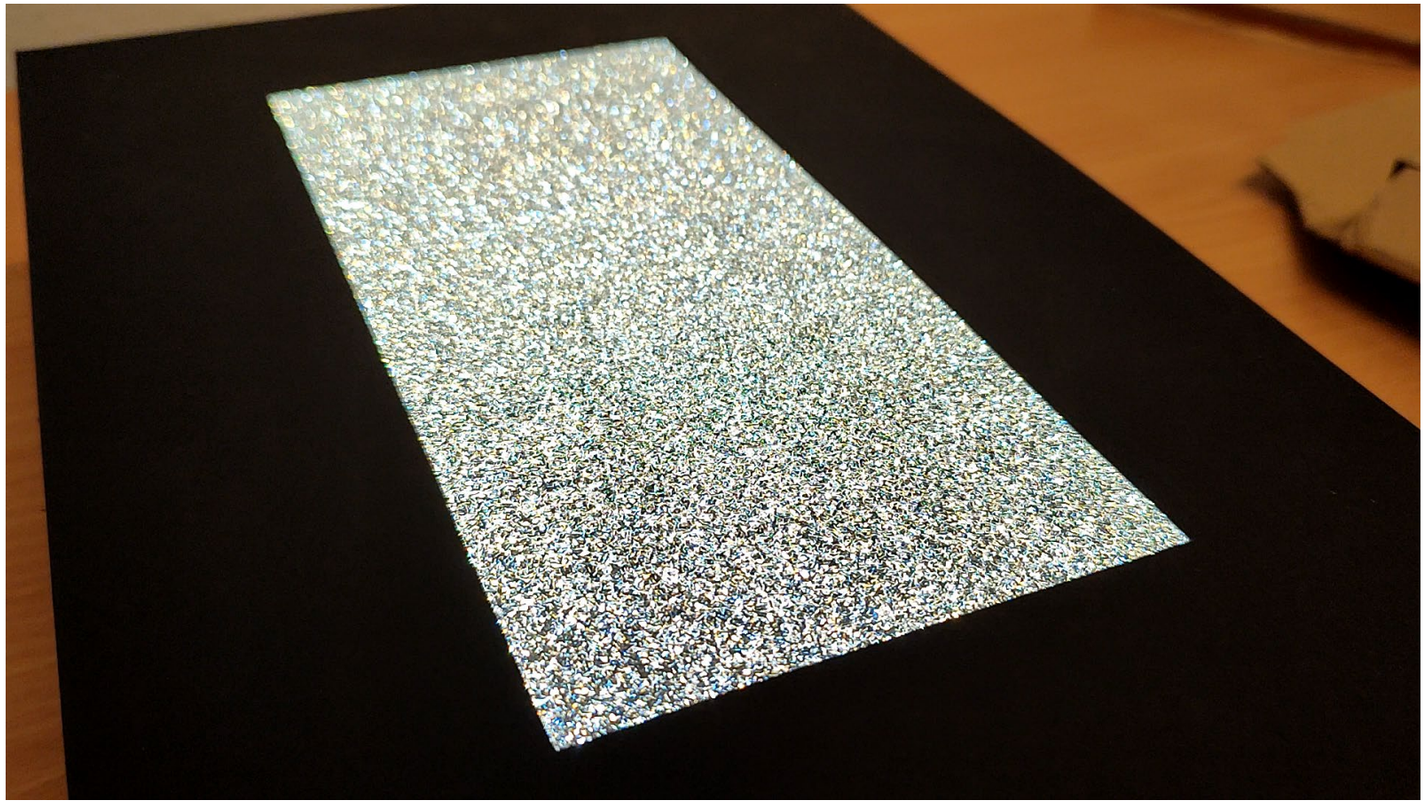
video

v = 1 m/min

Roll-to-roll (R2R) replication: finished products

R2R UV imprint into high dispersion resin
+ R2R backside metallized Fraunhofer FEP
View: reflection

video



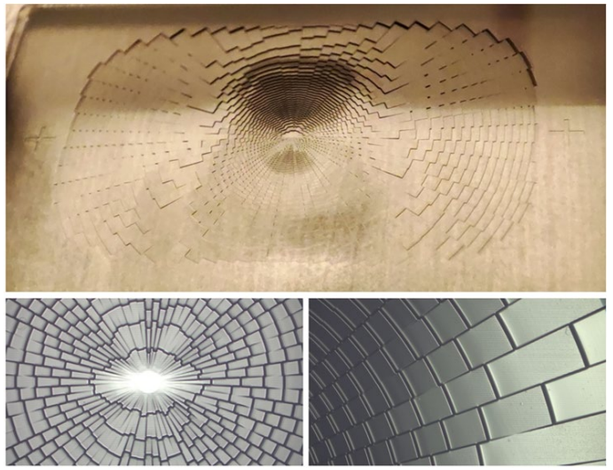
R2R UV imprint into high dispersion resin
View: transmission

Use Case 2: Interior Lighting for Trains

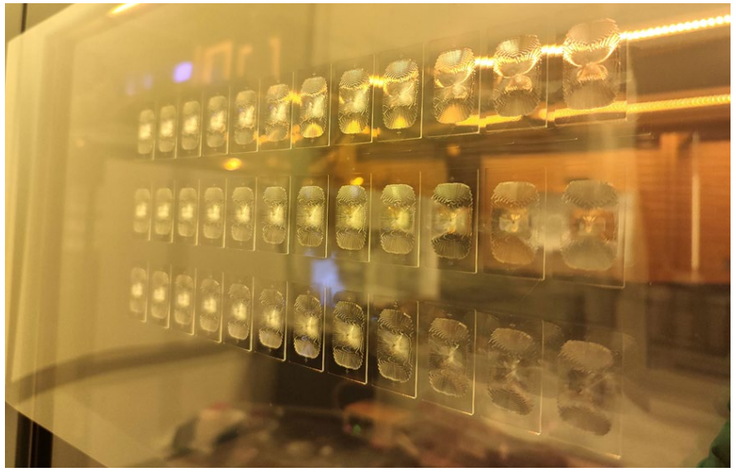
Application:
Freeform micro-lenses for a homogeneous large-area direct-lit luminaire as a linear lens array

Upscaling target: Grey Scale Lithography Mastering, Step & Repeat and Roll-to-Plate production
Freeform lenses with highest surface quality and shape fidelity

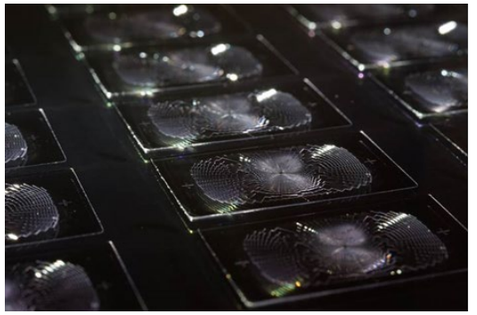
S&R working stamp

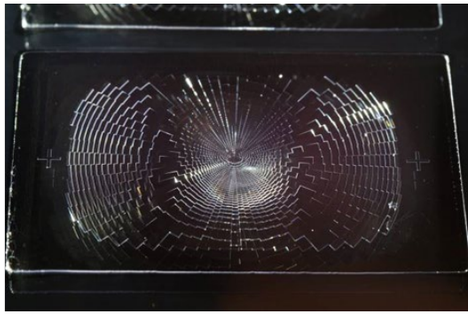


Polymer shim



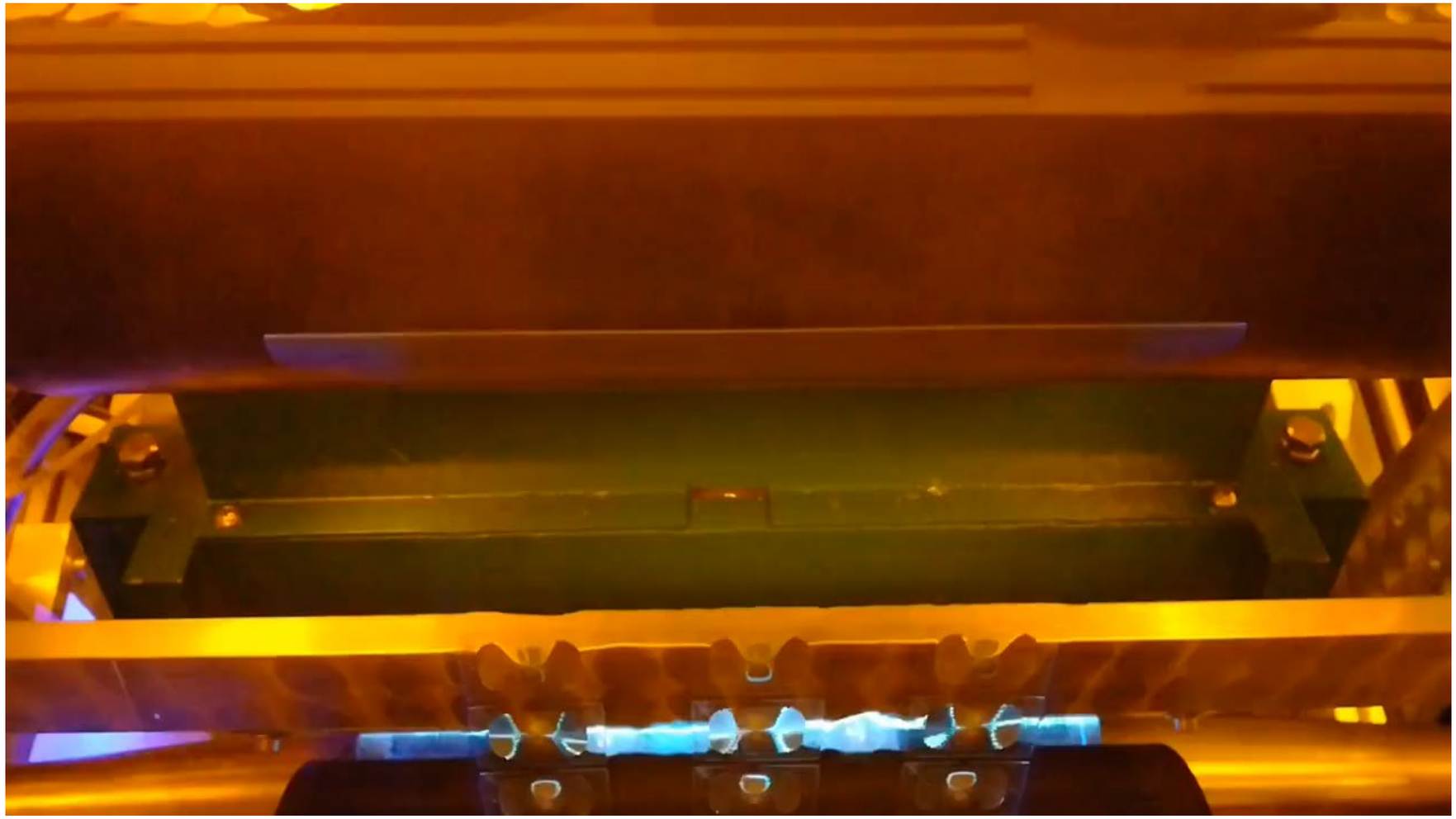
Roll-to-Plate lens arrays





MORPHOTONICS

Roll-to-Roll replcation of FF-Microlenses



Special Thanks to
Ursula Palfinger, Roman Trattnig, Markus Postl, Stephan Ruttloff

Thank you for your attention!

JOANNEUM RESEARCH
Forschungsgesellschaft mbH

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