

SOLNIL

Nanoimprint your world

Wafer-scale Fabrication of Ceramic Nano and Micro-optical Elements

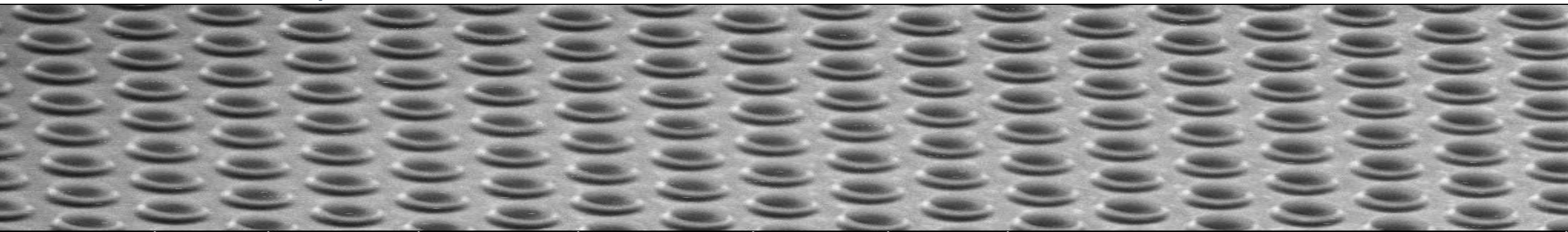
EPIC Technology Meeting on Photonics for Miniaturized
Optics: From Components to Use-cases at Sony DADC

September 19, 2024

Badre KERZABI, CEO

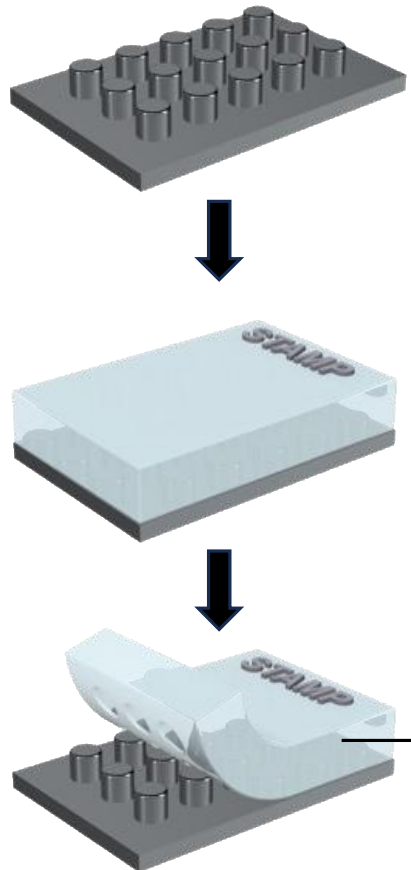


Marseille, FRANCE

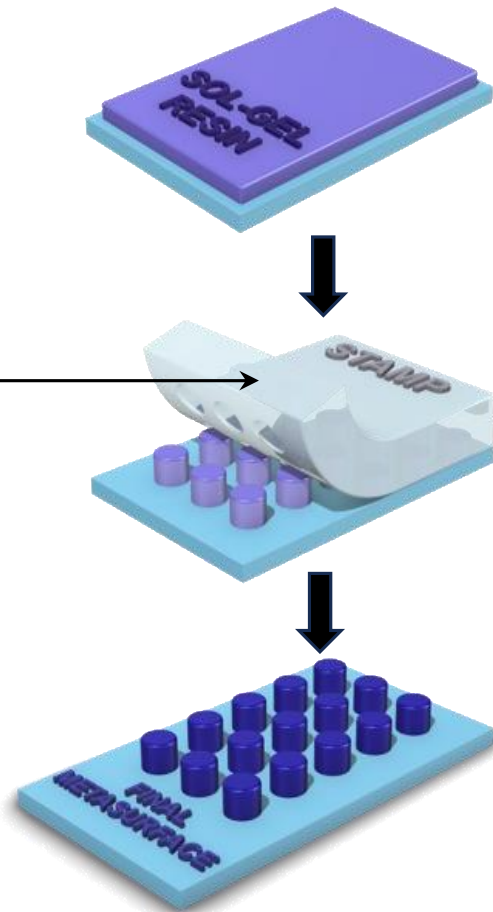


Direct Nanoimprinting of Ceramics

Stamp Fabrication



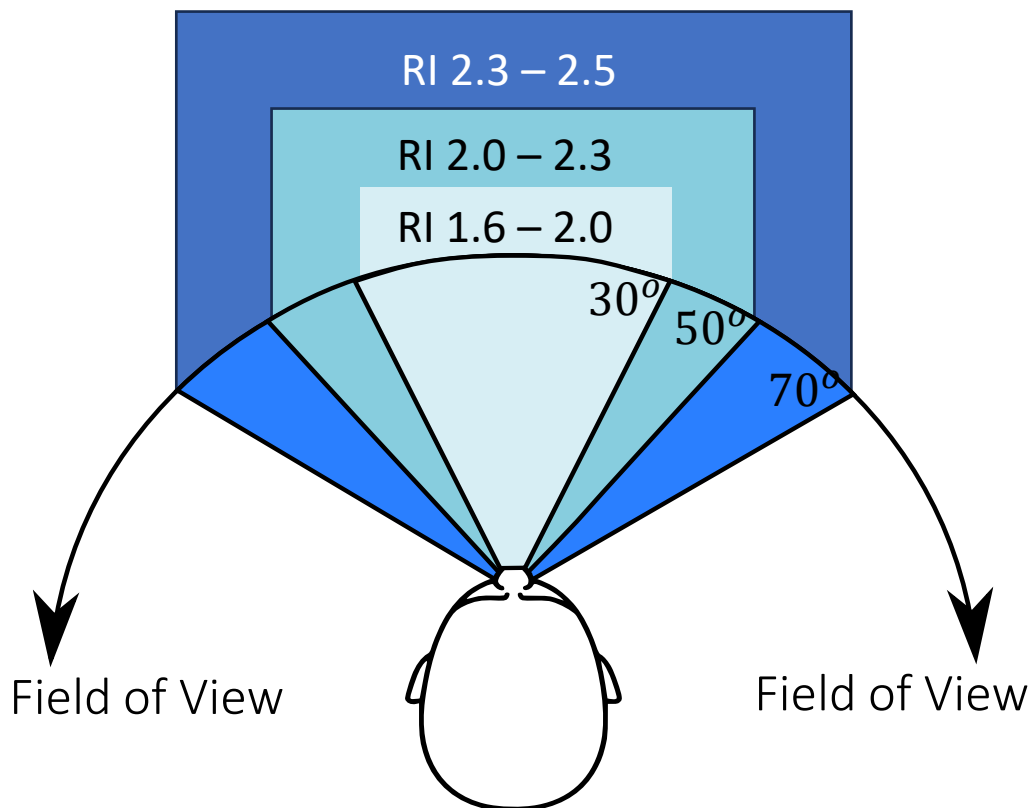
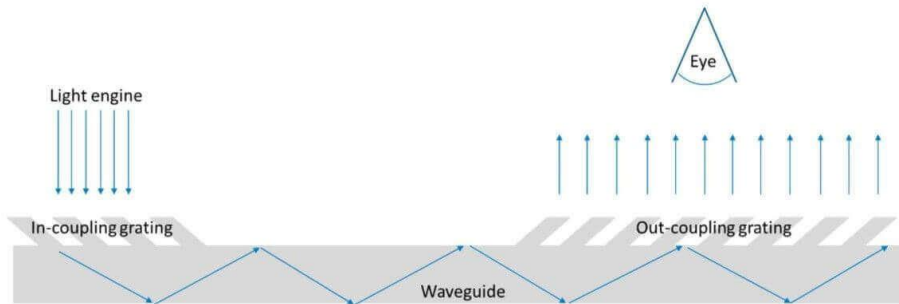
Nanoimprinting



- Compatible with existing NIL tools
- Wide range of Ceramics (Oxides)

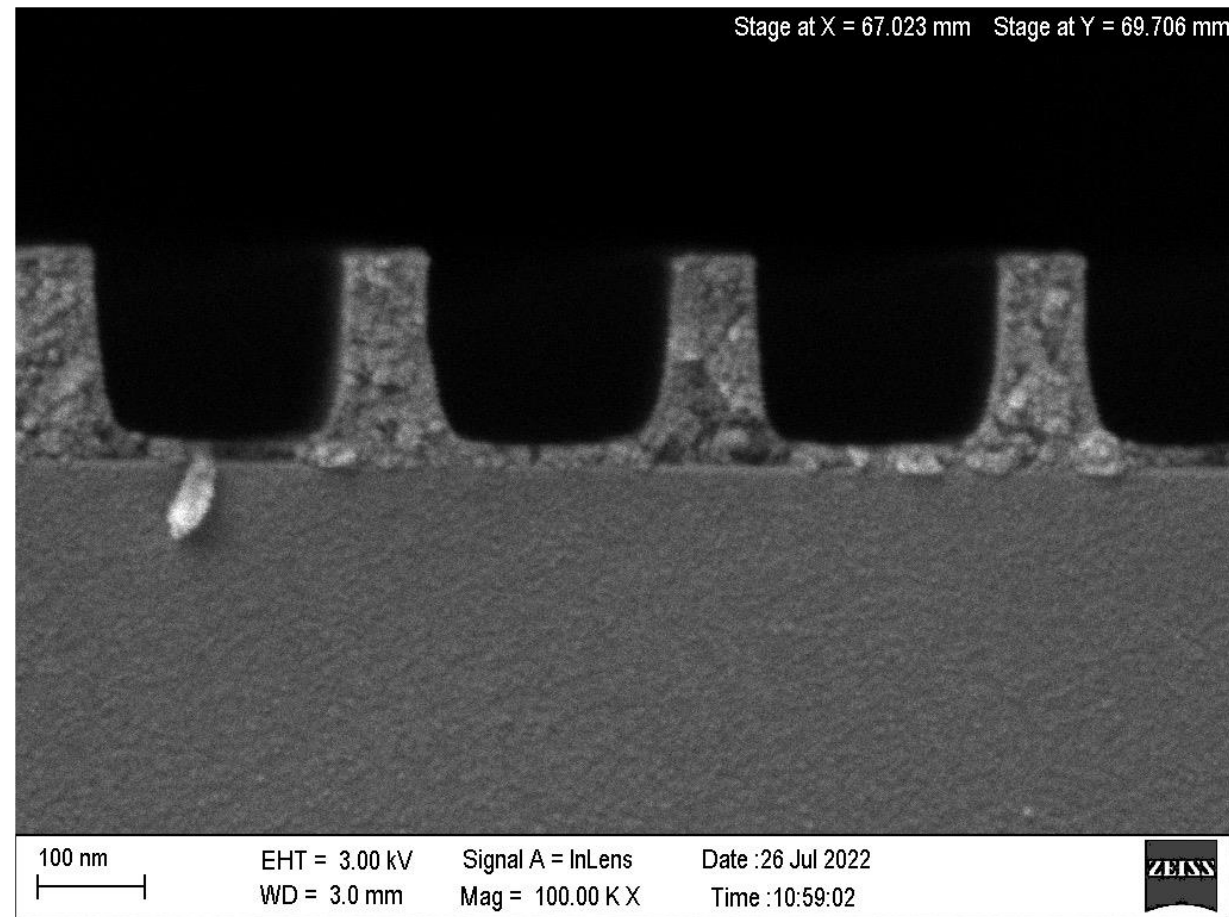
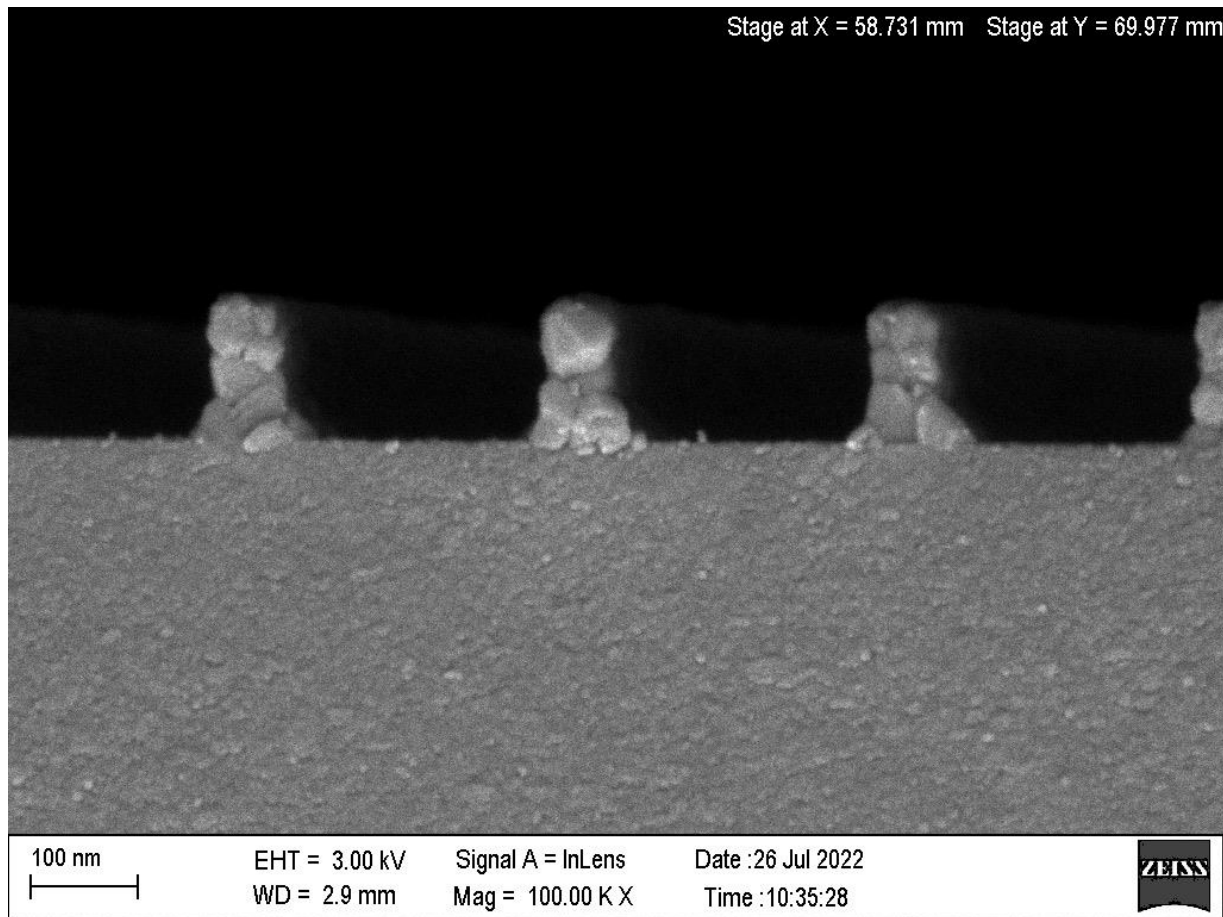
MATERIALS	RI@520nm	STRUCTURE
TiO ₂	2.3 – 2.6	Anatase
TiO ₂	2.0 – 2.3	Amorphous
SiO ₂	1.45	Amorphous
SiO ₂ porous	1.15	Amorphous
Al ₂ O ₃	1.6	Gamma
ZnO	1.7	Wurtzite
HfO ₂	1.95	Monoclinic
VO ₂	3.3	Monoclinic

TiO₂ for Augmented Reality



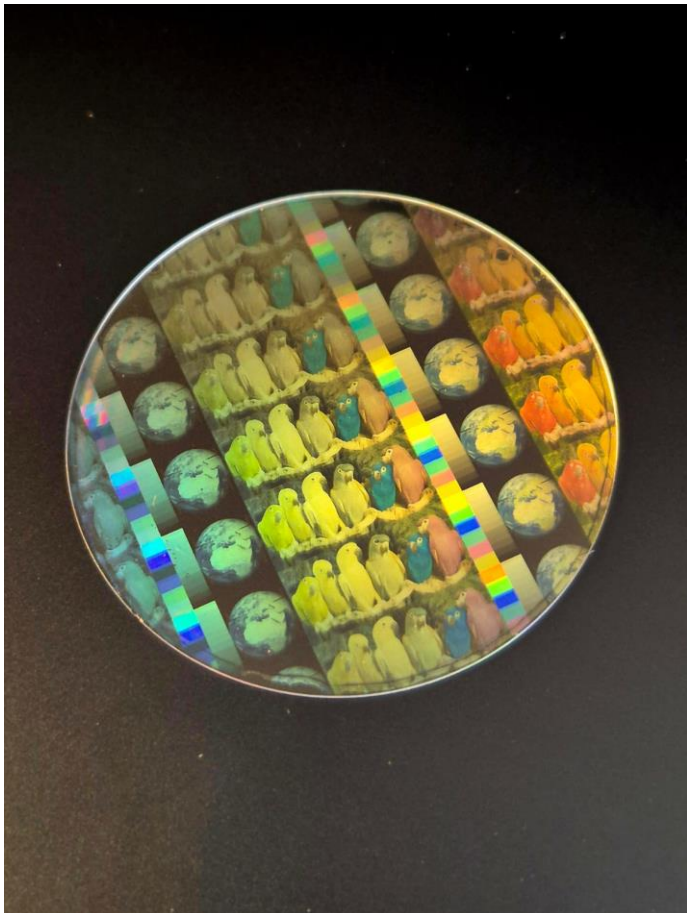
- Currently available high RI NIL materials (TiO₂ nanoparticles) have limited optical performances: **<2.0 RI, yellowing, haze**
- Etching of dielectric films deposited by ALD/PECVD/LPCVD has **significant impact on cost**
- SOLNIL developed NIL materials **with RI up to 2.5 and ALD-like quality**

TiO₂ crystallization control



Sol-gel formulation and curing process optimized to achieve grains < 6nm

TiO₂ structural colors



TiO₂-based replica on glass (~2 cm x 1 cm). Pixel size 12 μm x 12 μm

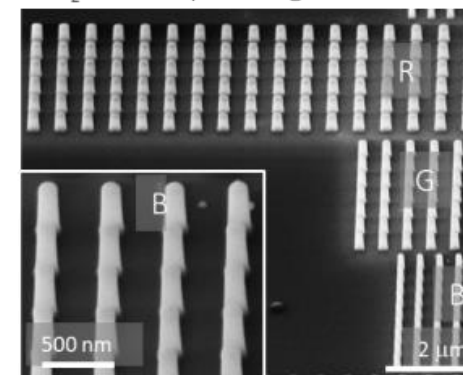
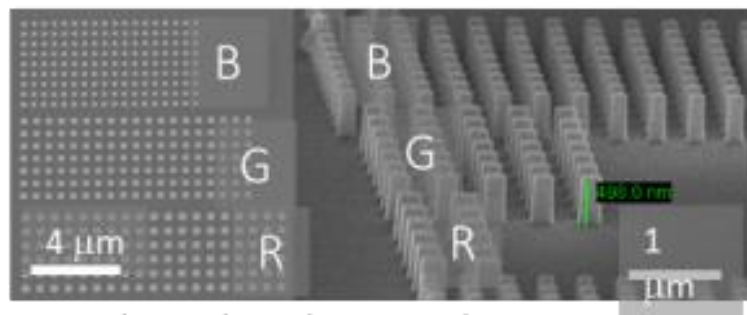
OBJECTIVE MICROSCOPE IMAGE (X5) INTEGRATION ANGLE ±15 DEGREES

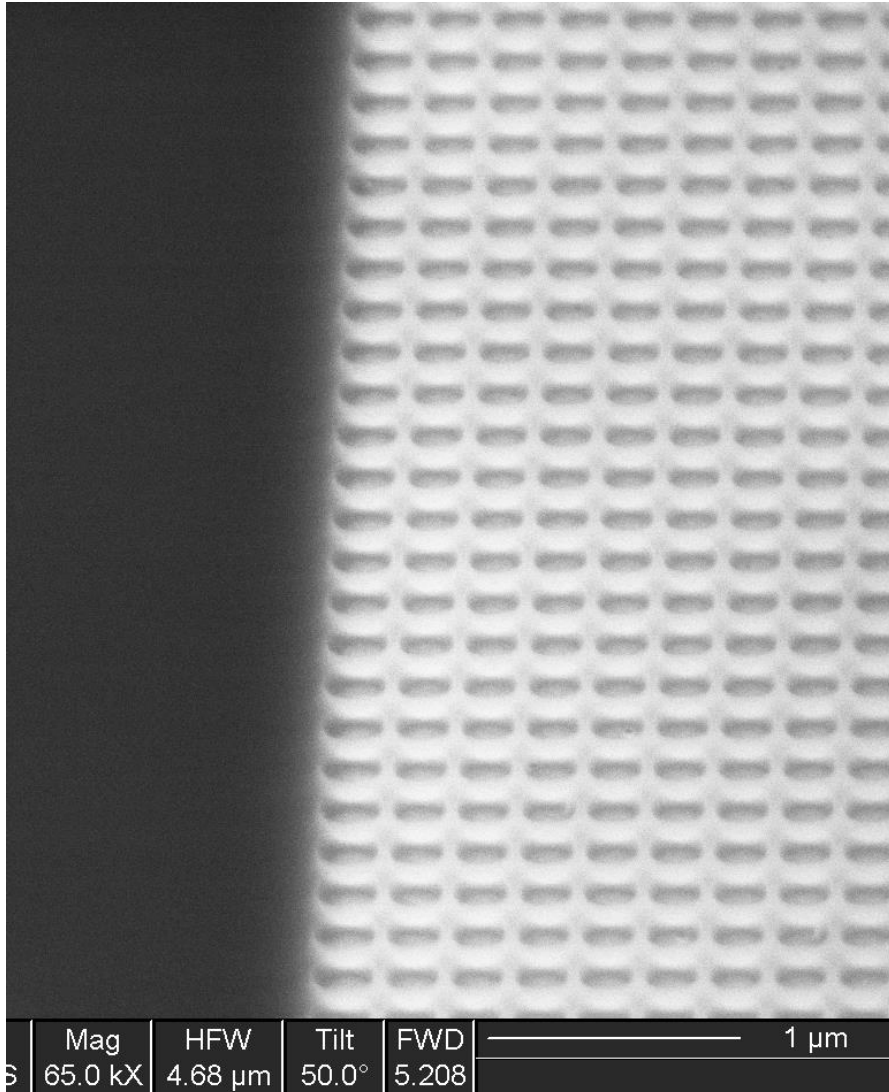


SMARTPHONE IMAGE, INTEGRATION ANGLE ±0.03 DEGREES (FROM 1.5 m DISTANCE)

TiO₂-based replica on glass

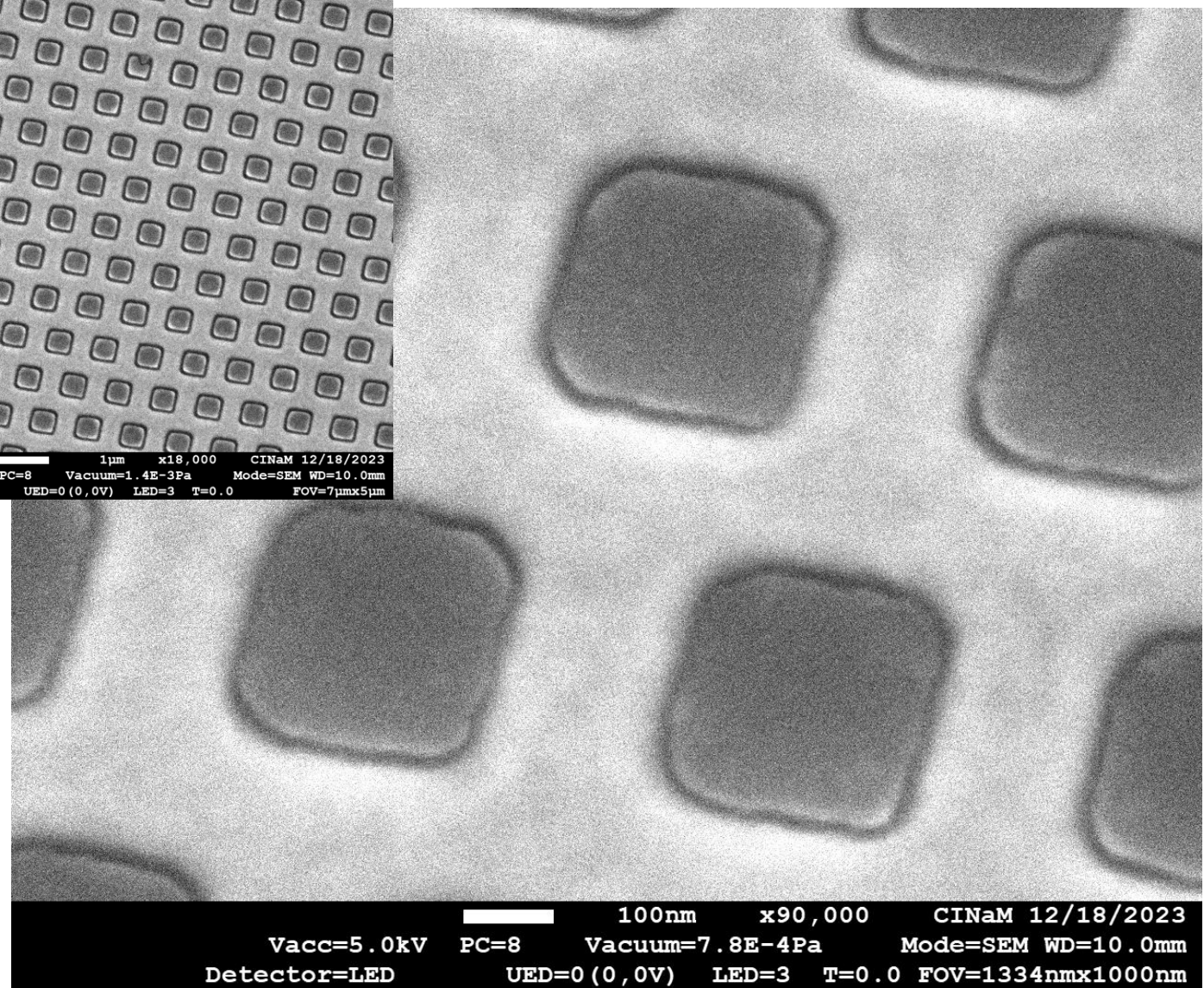
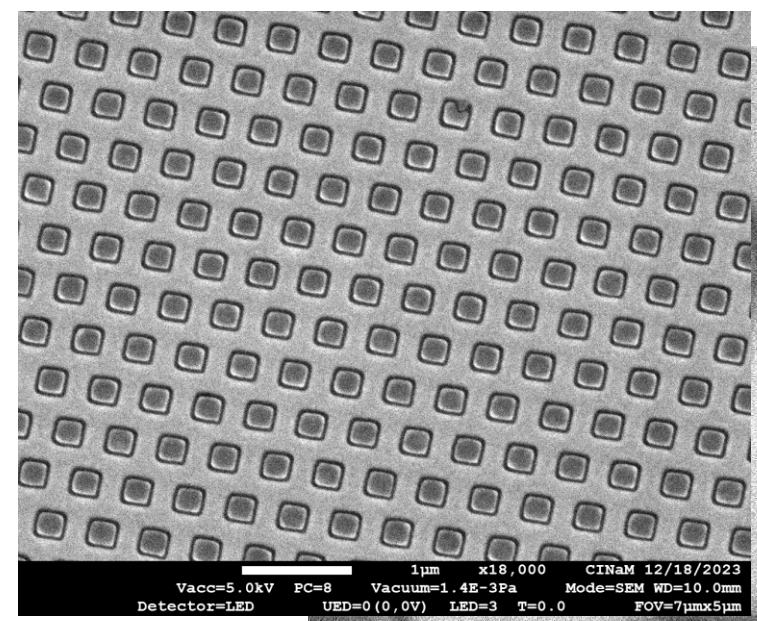
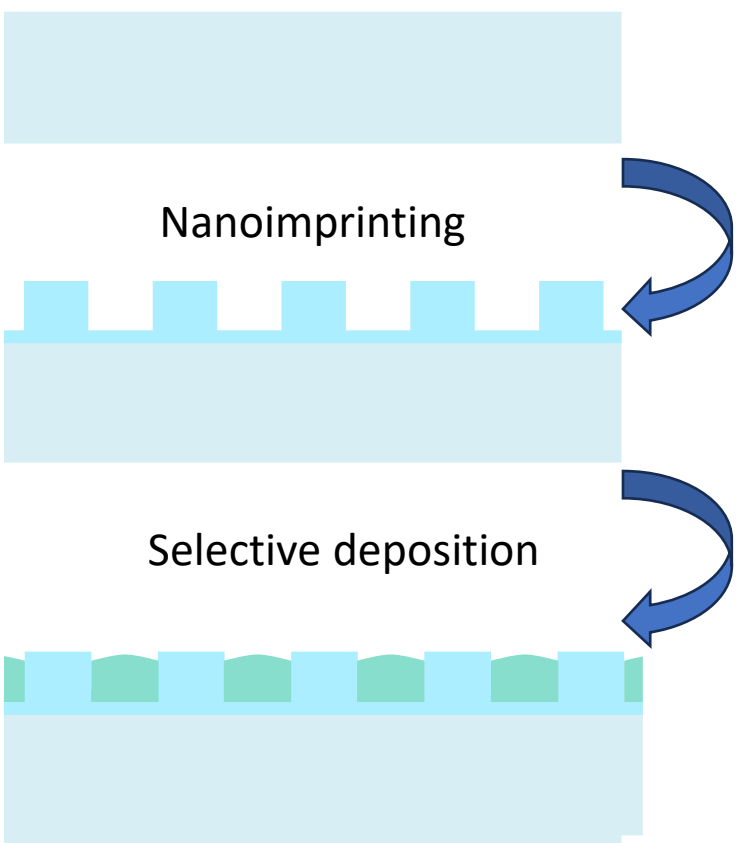
Si master mould

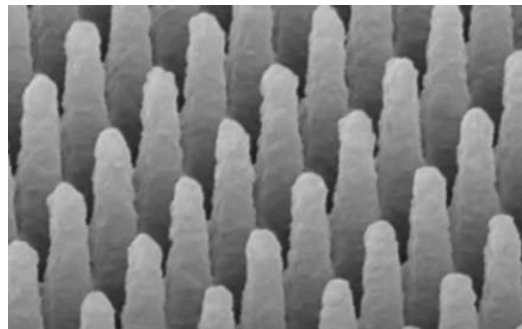
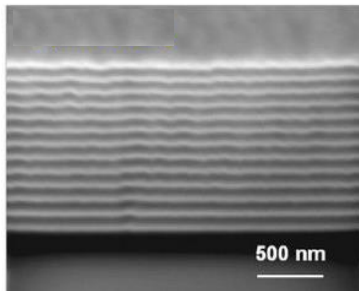
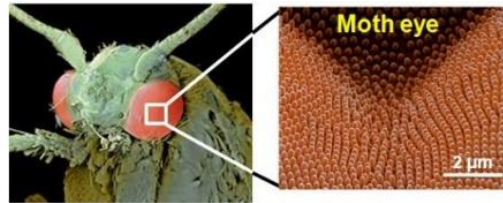
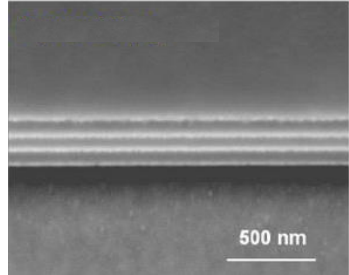
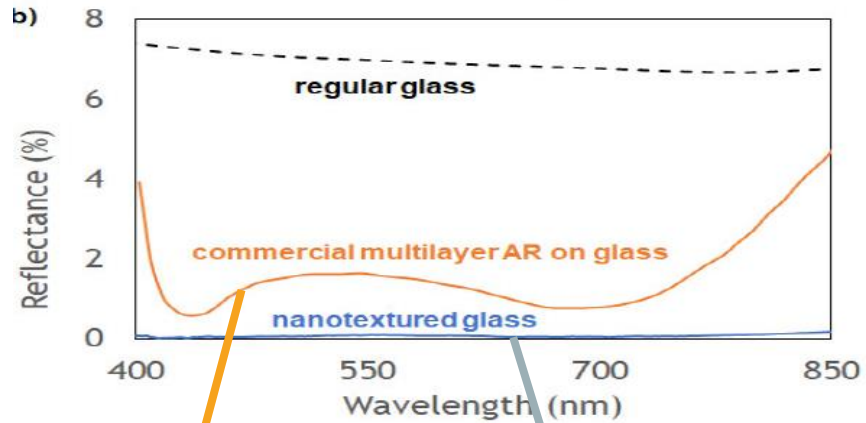




- Glass is the material of choice for applications where very low auto-fluorescence is needed
- Glass nanostructures can be directly nanoimprinted
- Hydrophobicity and polarity can be tuned

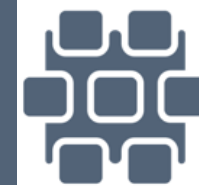
Selective deposition



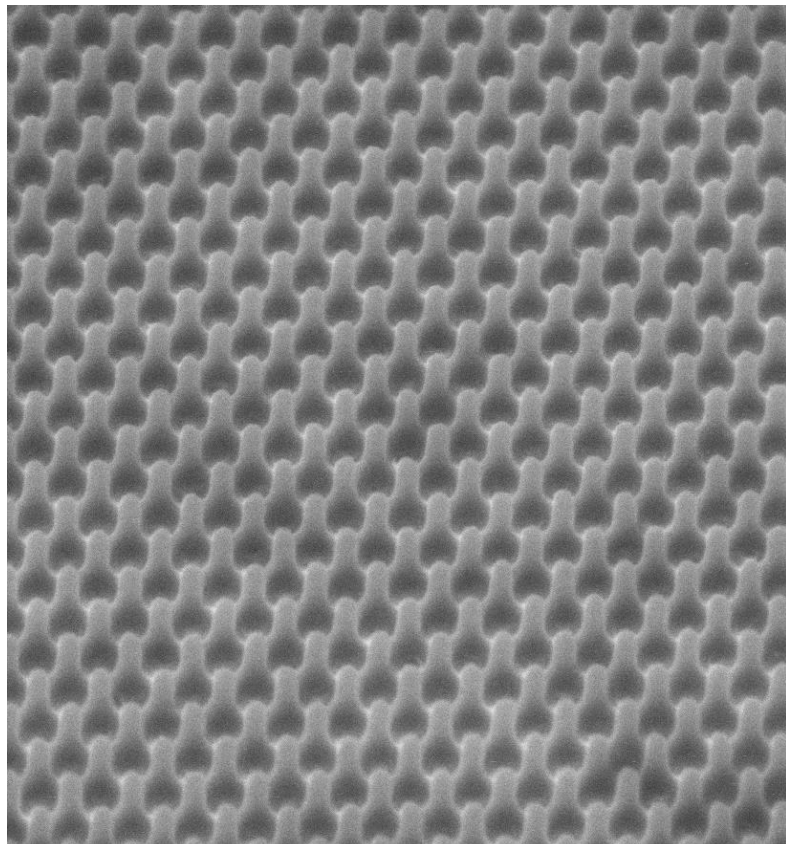


- Smooth transition from air to glass substrate
- Broadband operation and large acceptance angle (up to 60°)
- Higher laser damage threshold
- Etched glass proposed by several suppliers (Newport, Thorlabs)

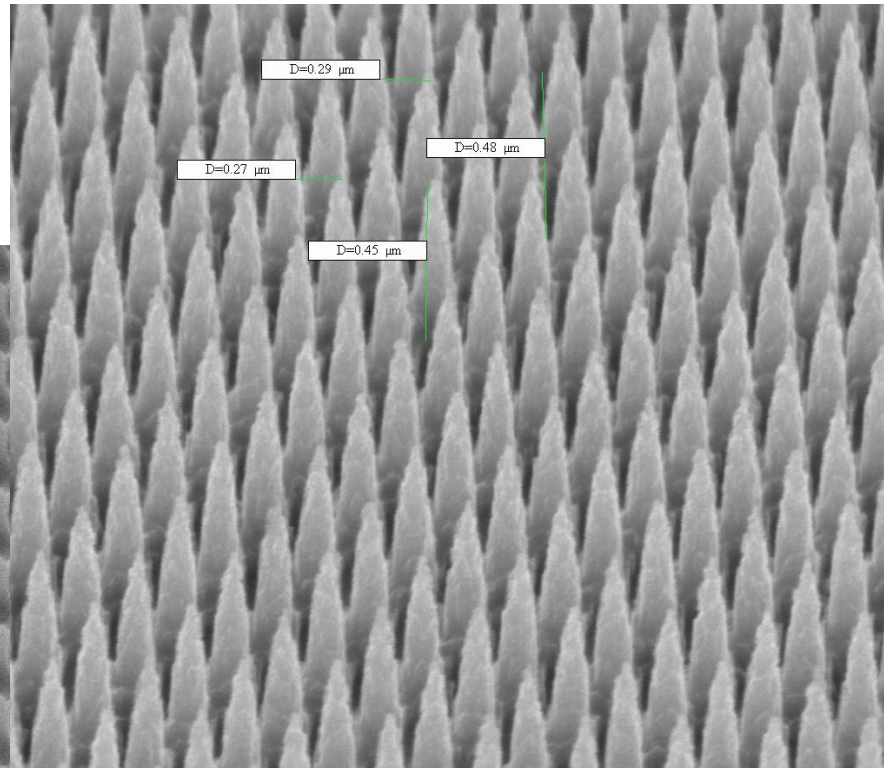
Nanoimprinted Fused Silica Moth-eye



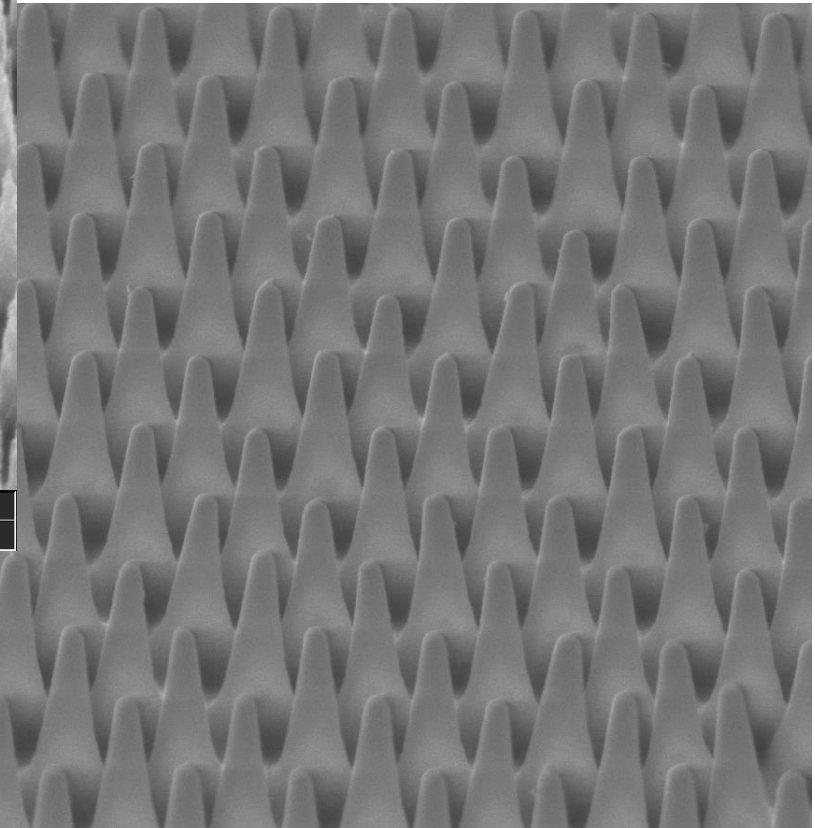
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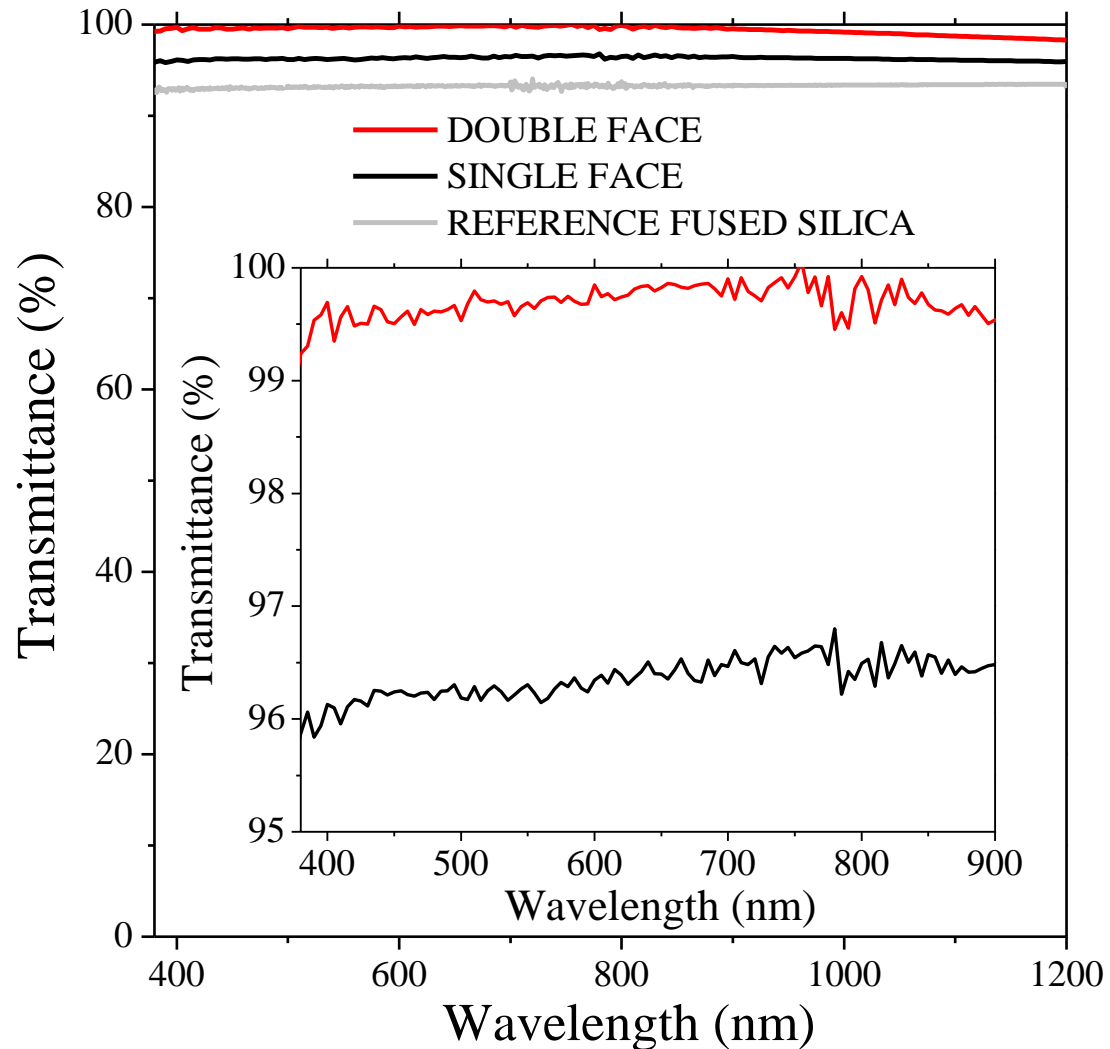
E-Beam	Spot	Det	Mag	HFW	Tilt	FWD	1 μm
5.00 kV	3	TLD-S	65.0 kX	4.68 μm	50.0°	5.041	



E-Beam	Spot	Det	Mag	HFW	Tilt	FWD	500 nm
5.00 kV	3	TLD-S	120 kX	2.53 μm	50.0°	5.346	



E-Beam	Spot	Det	Mag	HFW	Tilt	FWD	2 μm
5.00 kV	3	TLD-S	35.0 kX	8.69 μm	50.0°	4.920	



@ VIS frequency (380-900 nm)

T > 99.5% for double face

T > 96% for single face

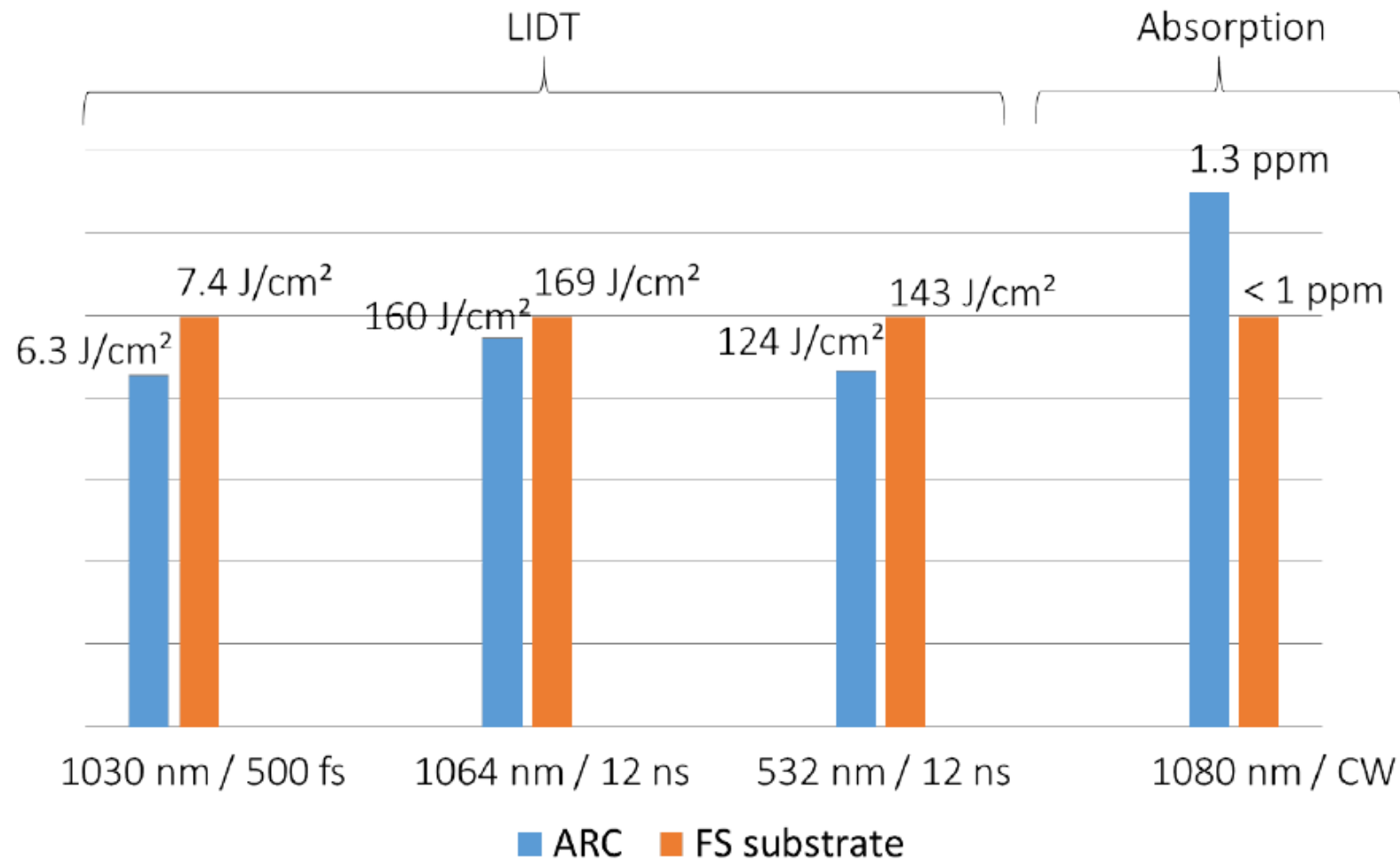
@ NIR frequency (800-1200 nm)

T > 99.5% for double face

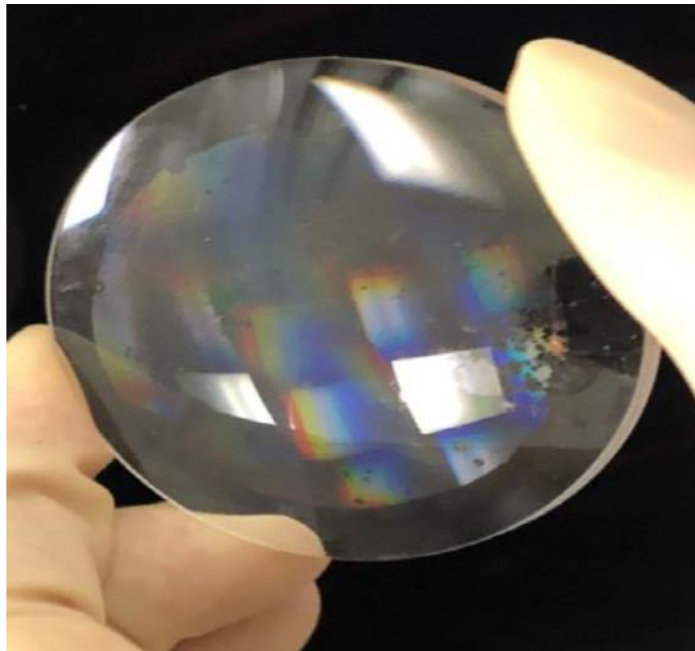
T > 96% for single face

Performances are maintained for incidence angles up to 50°

Lased Induced Damage Thresholds

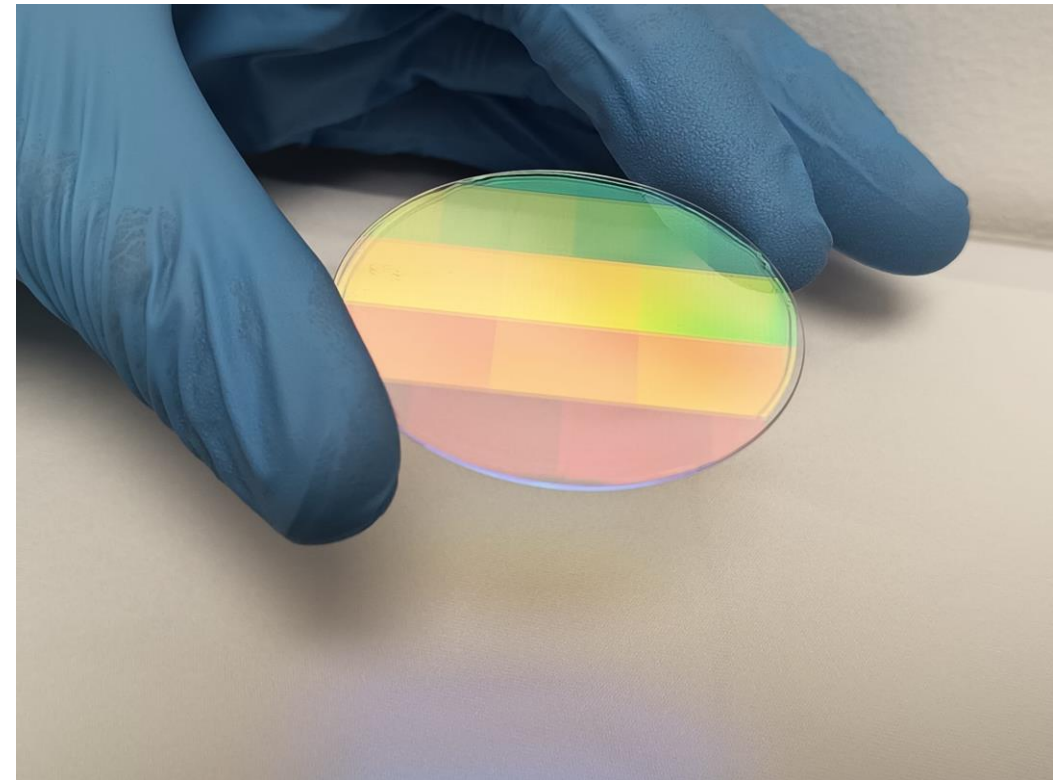


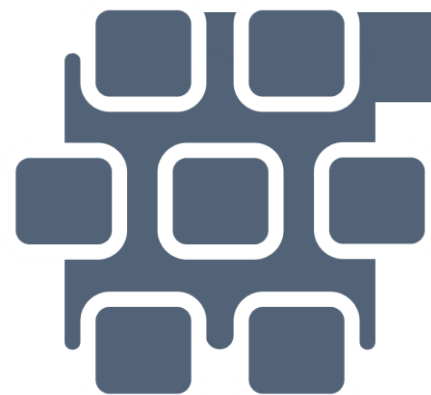
Nanoimprinting on curved surfaces



THALES
Building a future we can all trust

Fused Silica Gratings





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Thank you!



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