Funded by the European Union

OPTIMAL-Platform

PRESENTED BY MARKUS POSTL,
JOANNEUM RESEARCH

OPTIMAL

Funded by the European Union

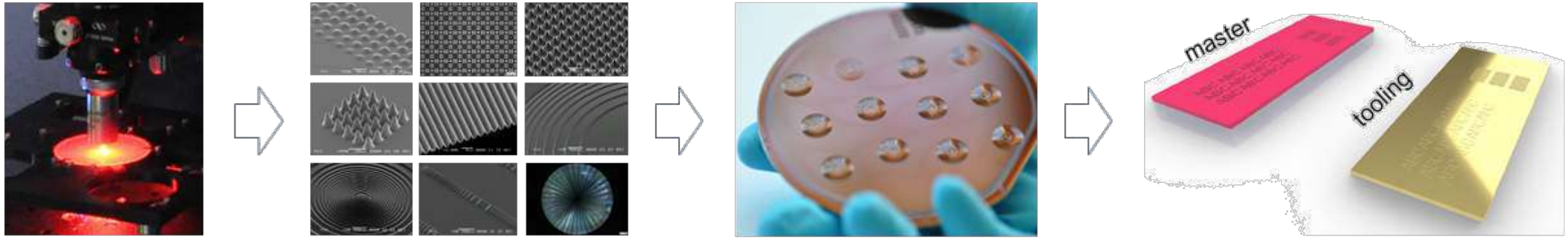
AutOmated Maskless Laser Lithography Platform for First TIme Right Mixed ScALe Patterning

The **OPTIMAL** project will integrate for the first-time different laser lithography technologies, quality monitoring systems and processes in one platform to improve the manufacturing of original structures, known as masters, needed for key-enabling replication techniques in optical, industrial, medical device fabrication.

Starting date of the project: 01/10/2022 - Duration: 48 months

Homepage: https://www.optimal-project.eu

Keywords: Area 2000 cm^2, Depth ≥ 150 µm, Speed 1 cm^2/min, Critical dimension < 150 nm, Dimension 2.5D and 3D



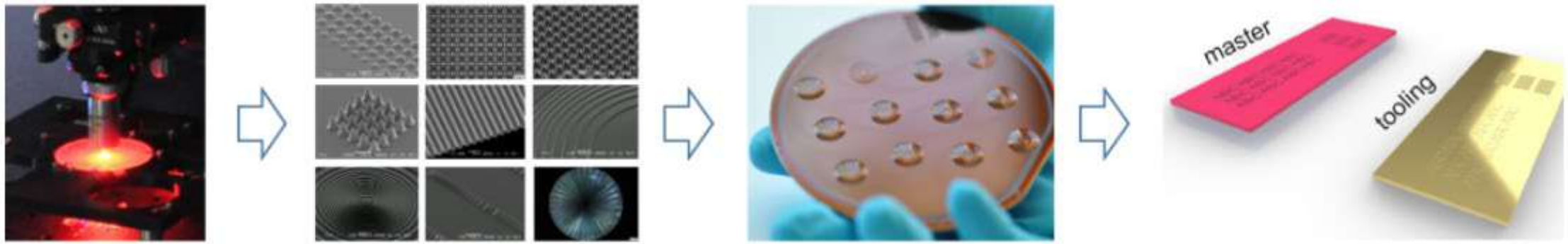
Partners:

Sony DADC, BASF We create chemistry, hypervision, micro resist technology, Slovak Centre of Scientific and Technical Information, DeltaPix Discover the Details, Università di Parma, University of Žilina, Joanneum Research

Project Description

- The OPTIMAL project will integrate **for the first-time** different laser lithography technologies, quality monitoring systems and processes in one platform for the development of **structures with high depth, dimensions in the range from 100 nm to sub-mm, 2D&3D shape on flat surface, combining parallel & serial patterning, no need for external treatments on samples, increased speed and large area**.

- The OPTIMAL project uses **self-learning algorithms to optimize the virtual photomask** as well as **integrates methods for an inline control of the laser patterning**.



Partners

JOANNEUM RESEARCH FORSCHUNGSGESELLSCHAFT MBH Austria

CENTRUM VEDECKO TECHNICKYCH INFORMACII SLOVENSKEJ REPUBLIKY Slovakia

SONY DADC EUROPE GMBH Austria

MICRO RESIST TECHNOLOGY GESELLSCHAFT FUER CHEMISCHE MATERIALIEN SPEZIELLER PHOTORESISTSYSTEME MBH Germany

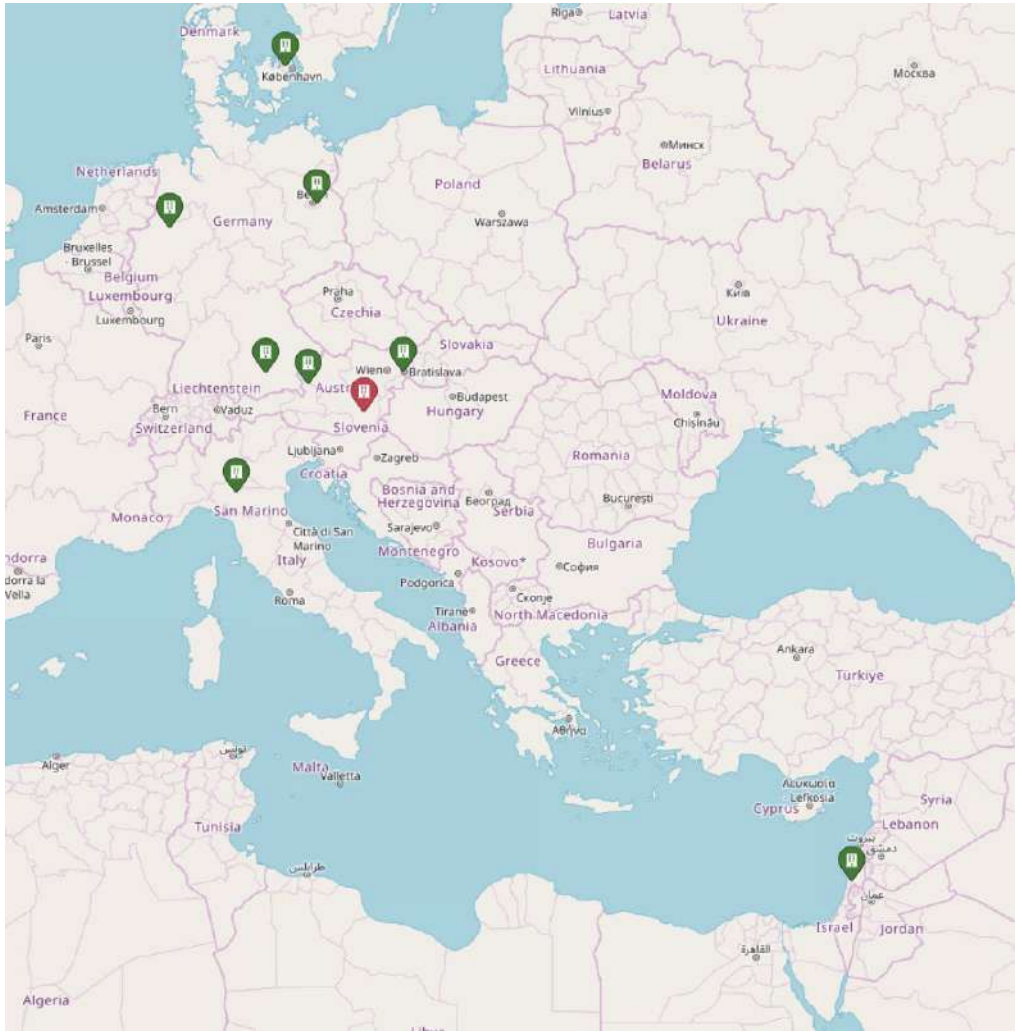
DELTAPIX APS Denmark

BASF COATINGS GMBH Germany

UNIVERSITA DEGLI STUDI DI PARMA Italy

HYPERVISION LTD Israel

UNIVERSITY OF ŽILINA Slovakia



Multidisciplinary Expertise

The OPTIMAL approach involves various disciplines, which interact with each other in order to achieve the project objectives.

- **Material research and photochemistry** is needed to develop suitable photoresists (MRT).
- **Knowledge of laser technology** is required to develop novel laser lithography methods, machines, and processes (JOR, UZA) .
- **Electronics** finds application in optical based sensors for in-line monitoring, controlling laser sources and patterning (ILC, DPX).
- **Software engineering expertise** completes the required skills for the development of self-learning algorithms for the generation of virtual photomasks (UPR) .
- **Mechanical and environmental engineering** are required for development of equipment and manufacturing processes from a life cycle assessment perspective (JOR).
- **Experts in training and communication science** will develop workshops and training materials to explain and promote the developed technologies to the broader public and stakeholders (ILC, UPR).

JOANNEUM RESEARCH	JOR
SLOVAK CENTRE OF SCIENTIFIC AND TECHNICAL INFORMATION	ILC
UNIVERSITY OF ŽILINA	UZA
Sony DADC	SDA
micro resist technology	MRT
DeltaPix - Discover the Details	DPX
BASF We create chemistry	BCD
UNIVERSITÀ DI PARMA	UPR
hypervision	HYP

Objectives

- Develop and optimize both negative and positive photoresist materials to increase their thickness (up to 150 µm for positive and 500 µm for negative) and area (up to 2000 cm^2), while maintaining homogeneity.
- Develop the first combined one-photon (1PL), two-photon laser lithography (2PL) and laser interference lithography (LIL) platform.
- Improve the current LIL process with the aim of lowering power consumption and the environmental impact of the laser source.
- Implement optical sensors for real time inline process monitoring directly in the OPTIMAL platform
- Develop self-learning algorithms for the optimization of virtual photomasks with a consequent reduction in the number of required iterations.
- Use the fully integrated OPTIMAL platform for fabricating structures.
- Demonstrate OPTIMAL technologies through the manufacturing of master tools for different use cases.
- Develop training packages targeting the scientific community and stakeholders.

OPTIMAL Impact

The OPTIMAL project aims to increase efficiency and yield by accelerating and upscaling the structuring process.

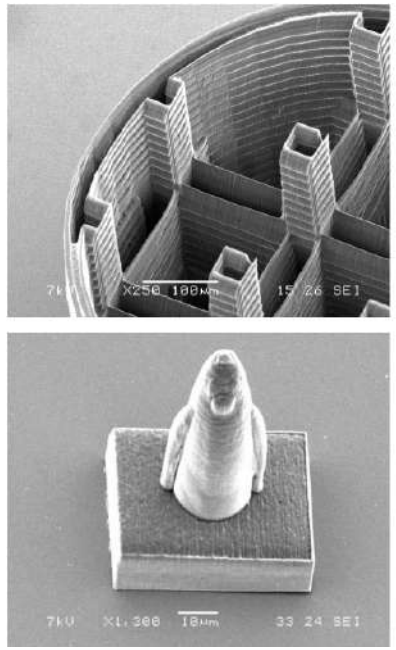
This will result in:

- First time right fabrication of the required structures.
- Lower resource consumption.
- Waste reduction.
- Lower CO2 emissions.
- Increased productivity.
- Cost reductions.

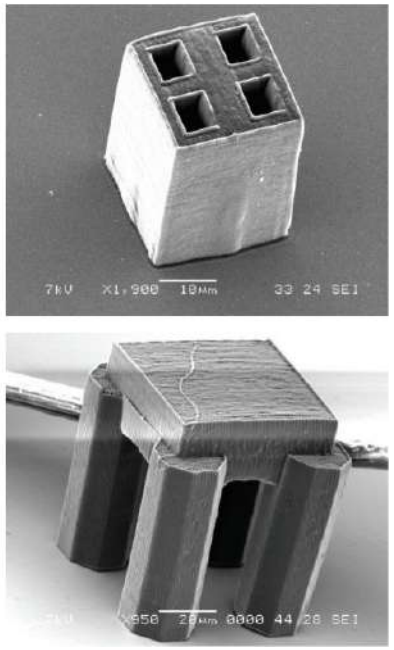
Laser Lithography

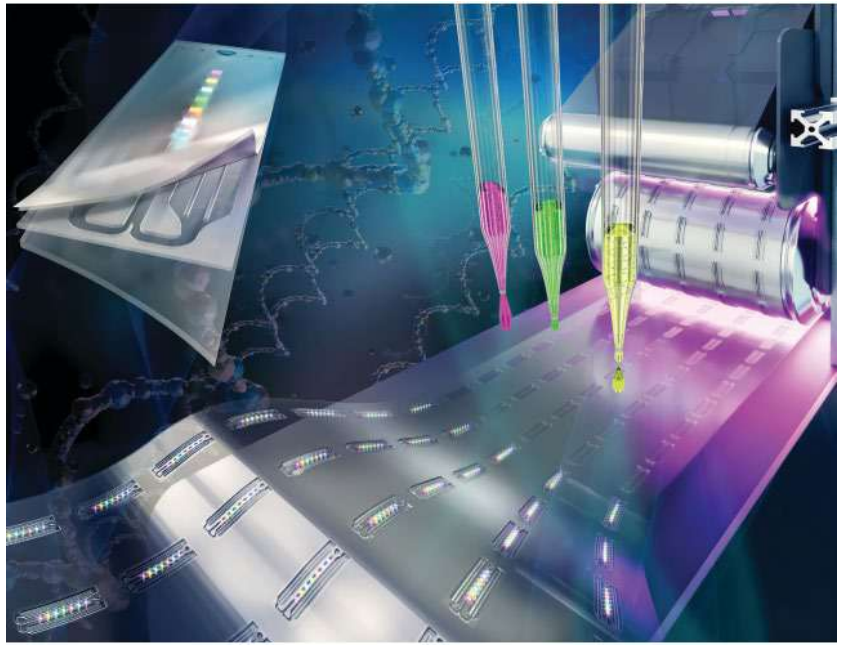
- Building structures that range in size from nanometers to millimeters.
- Write this structures over large areas (square centimeters).
- Production of original structures (masters) to create tools and molds.
- Using replication techniques such as UV-nanoimprinting or injection molding for mass production.
- Applications in fields such as optics, photonics, multifunctional surfaces, and lab-on-a-chip devices.

Image of the current maskless laser lithography setup at Joanneum Research MATERIALS



JLMN-Journal of Laser Micro/Nanoengineering Vol. 2, No. 3, 2007

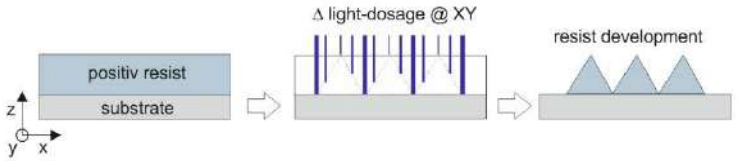




Lab Chip, 2020,20, 4106-4117

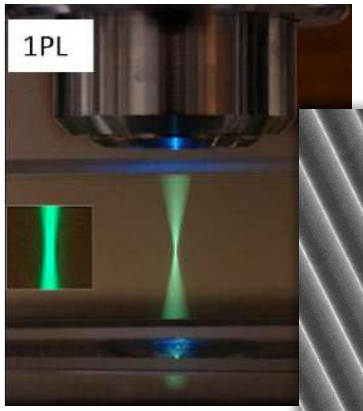
Techniques for Maskless Laser Lithography

One-Photon Lithography (1PL)

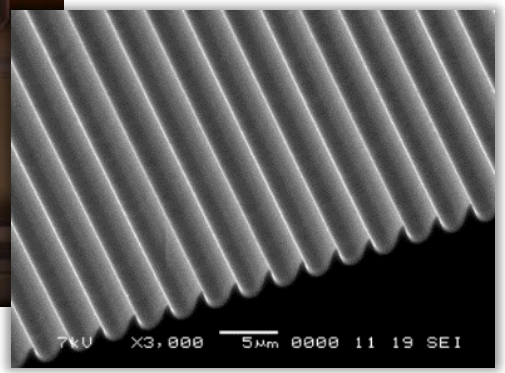


Grey-scale mode for 2.5D structures:

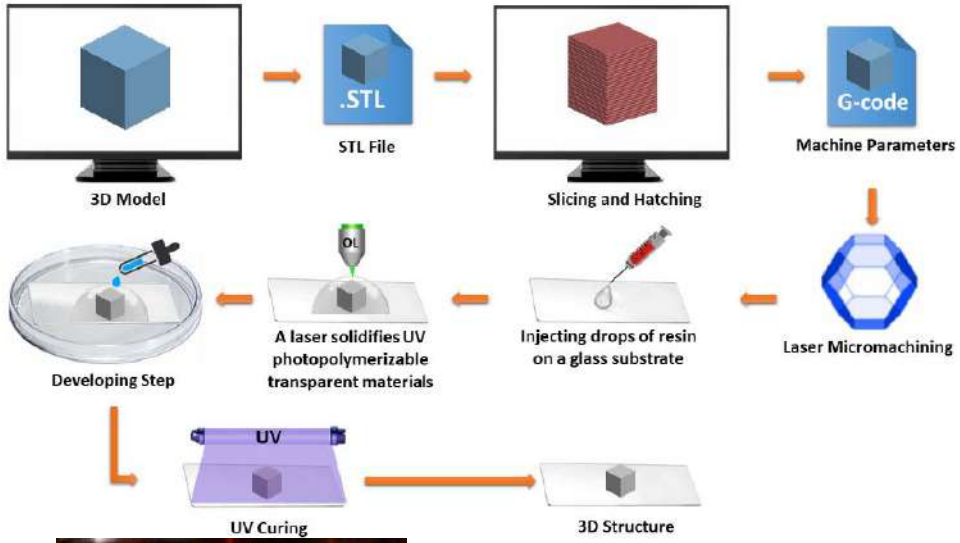
Exposure of a positive photoresist-coated substrate by XY- raster scanning under a focused UV- laser beam at synchronously controlled in laser intensity.

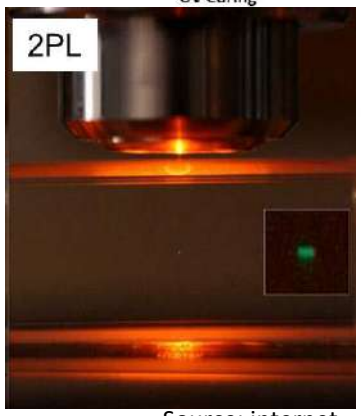


Source: internet

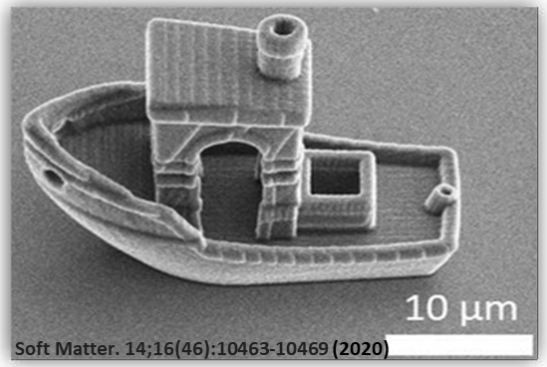


Two-Photon Lithography (2PL)



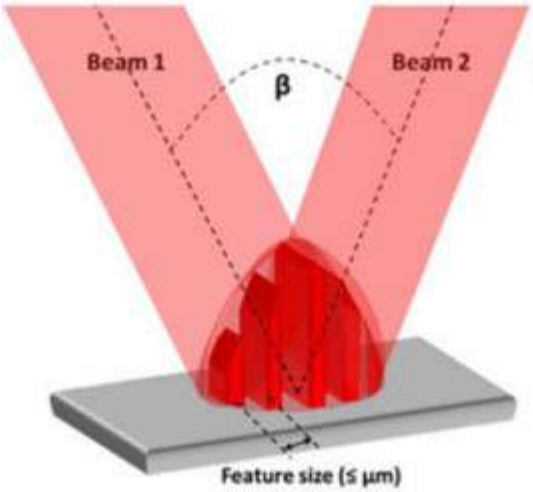


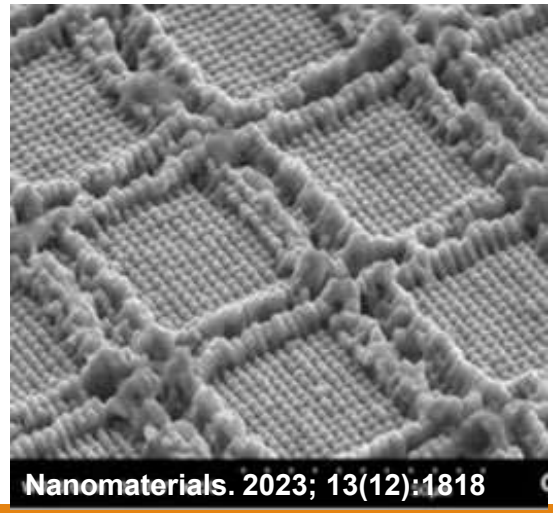
Source: internet



Soft Matter. 14;16(46):10463-10469 (2020)

Laser Interference Lithography (LIL)



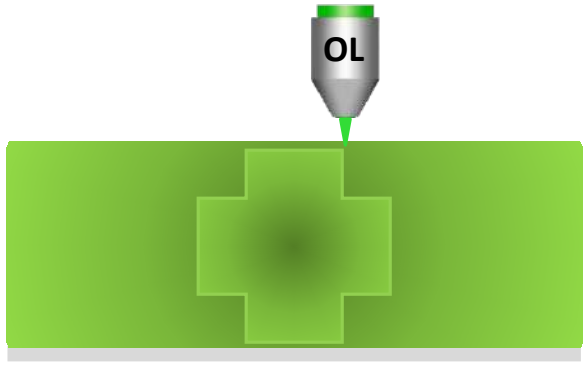


Nanomaterials. 2023; 13(12):1818

Photoresists (Materials)

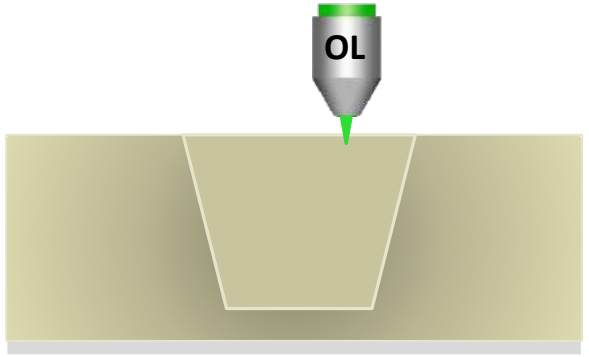
Negative

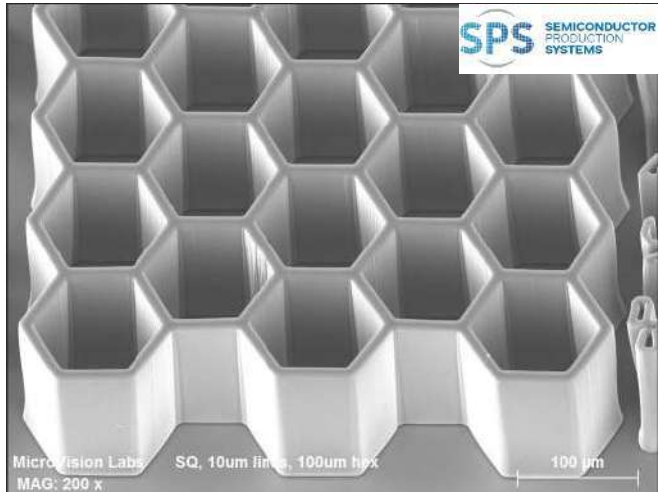
- ✓ Shorter processing time
- ✓ Lower operating cost



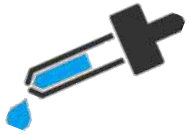
Positive

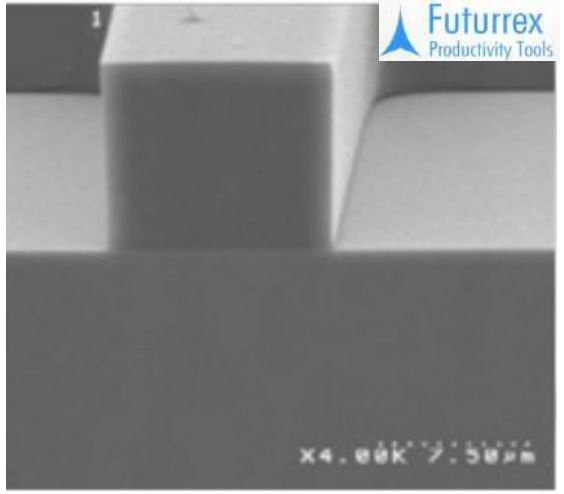
- ✓ Higher resolution





Developing step



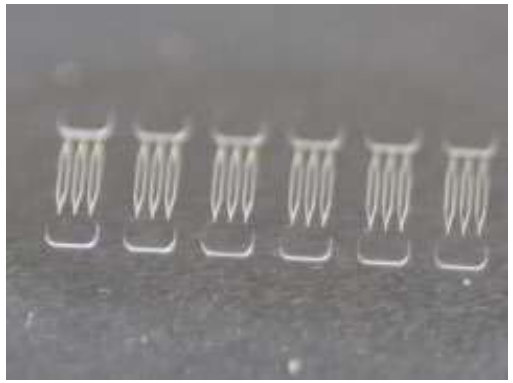


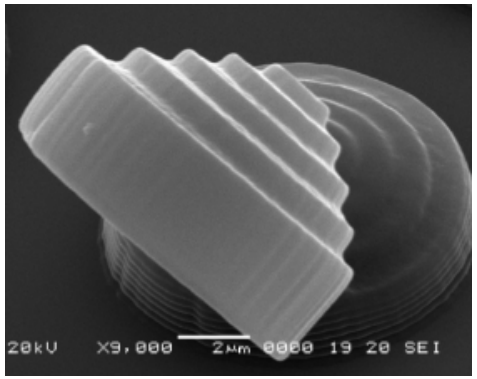
Additive manufacturing using negative tone resists

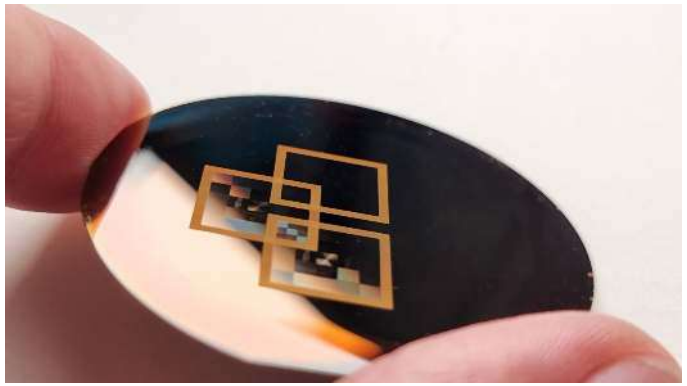
Subtractive manufacturing using positive tone resists

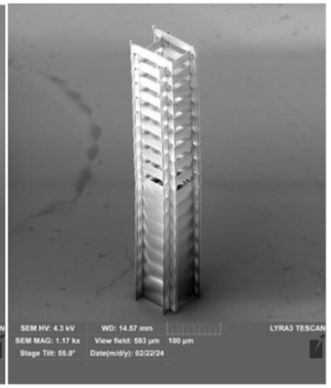
Challenges in Laser Lithography Techniques

- Limited depth of structures.
- Limited area over which structures can be produced with current systems.
- Low processing speeds.
- High power consumption for laser interference lithography.
- Multiple and expensive processes required for the development of hierarchical multifunctional structures at an industrial level.





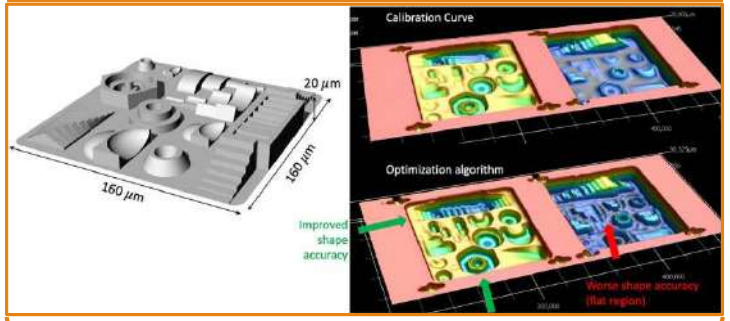




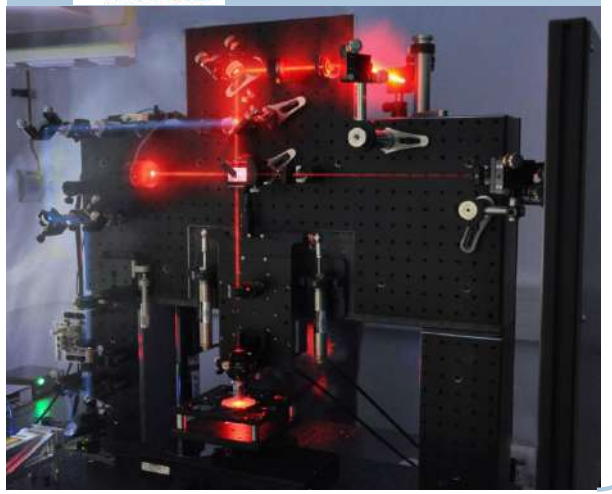
What is the OPTIMAL platform?

The Optimal platform is the combination of hardware and software modules to improve pattern fidelity, writing speed, structure heights and structuring area in the field of laser lithography

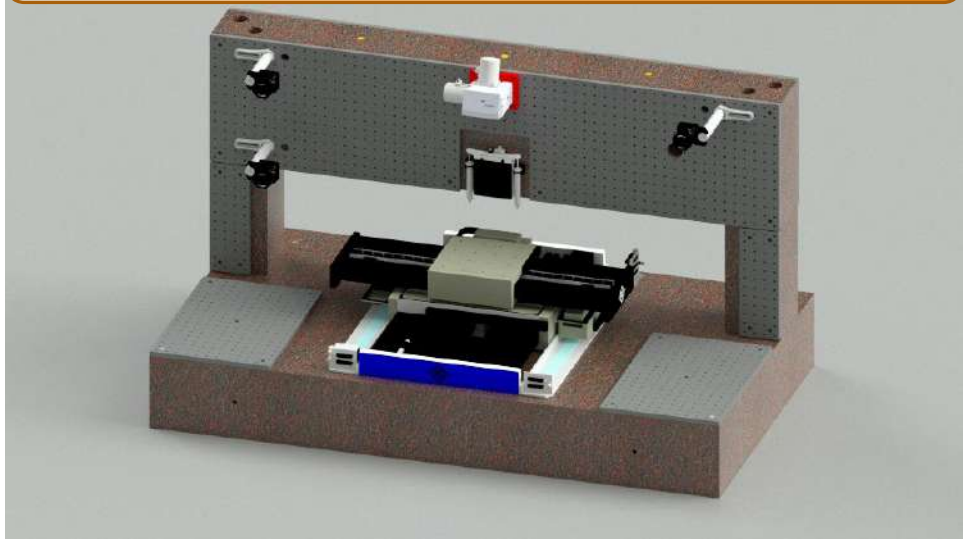
Self-learning algorithms



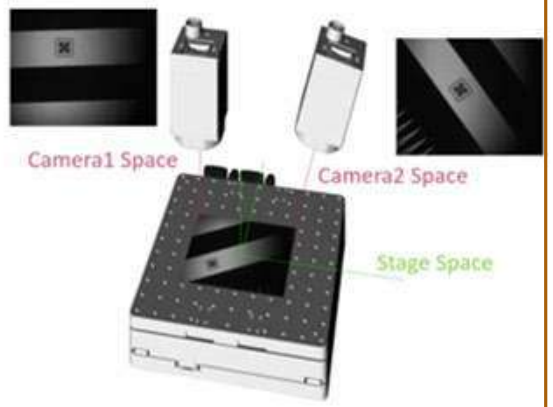
1PL & 2PL & LIL module



Lab & Stage system

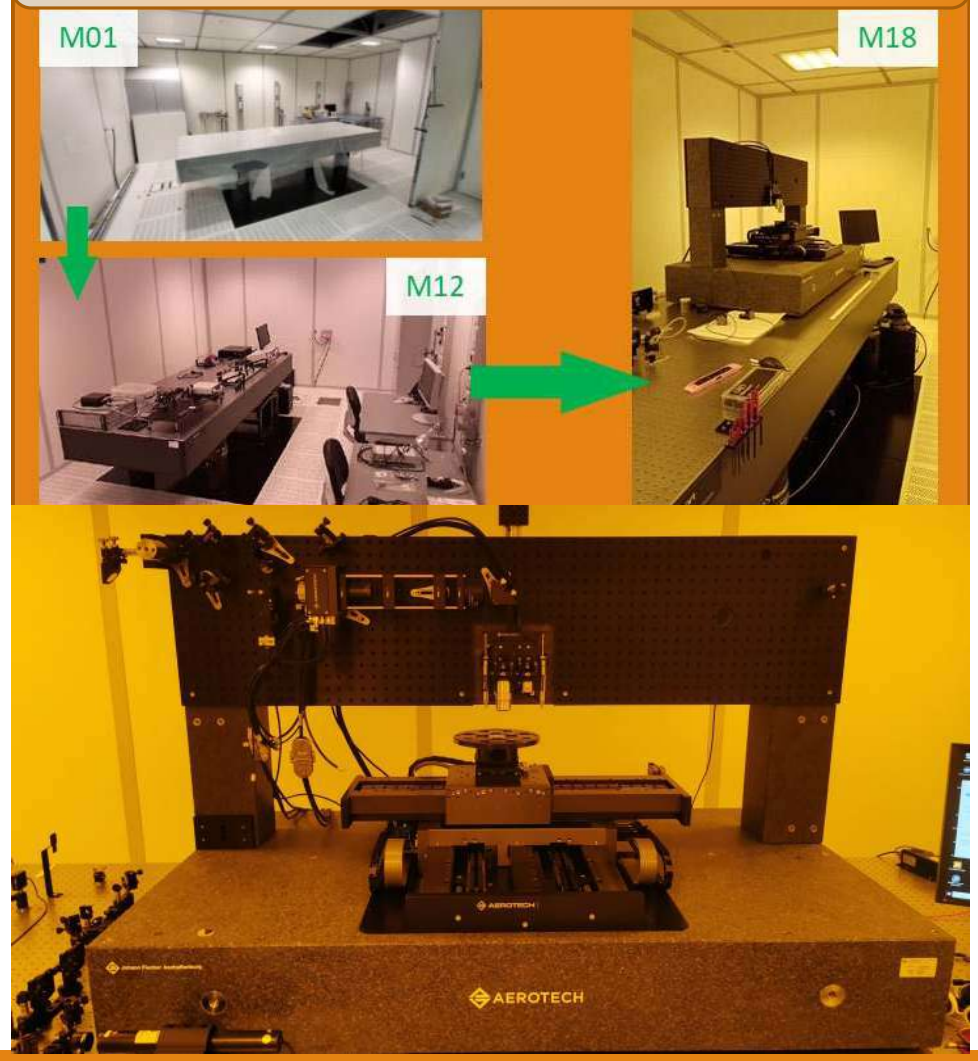


Monitoring and feedback control modules



OPTIMAL platform

Lab & Stage system



Laser laboratory to host the OPTIMAL-platform:

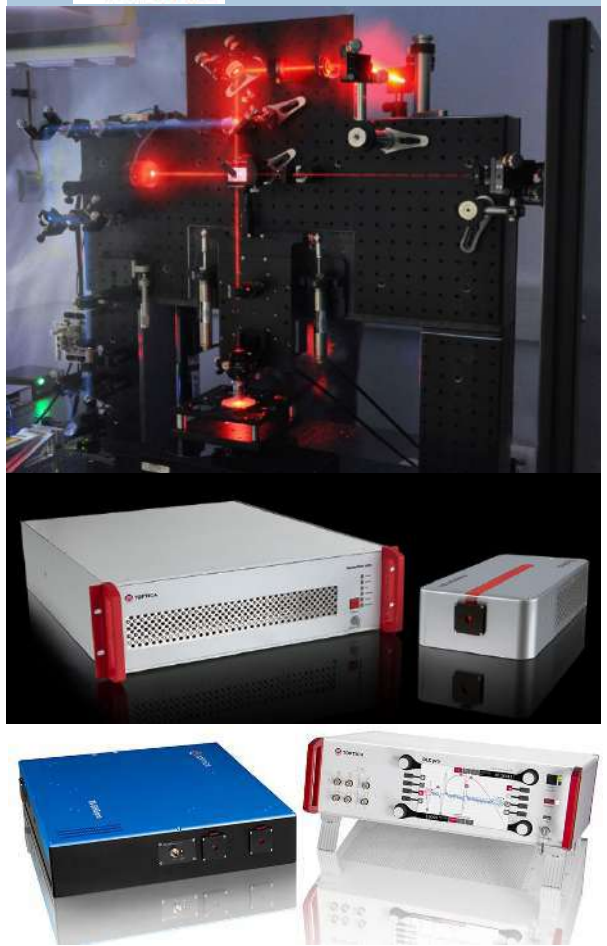
- ~ 40 m^2 in clean room, class 6 (ISO 14644)
- Thermally stabilized environment via special arranged FFUs
- Yellow light area

Main components of the OPTIMAL system:

- Optical table
- Customized high-precision XYZ positioning system
- Galvo scanner

OPTIMAL platform

1PL & 2PL & LIL module



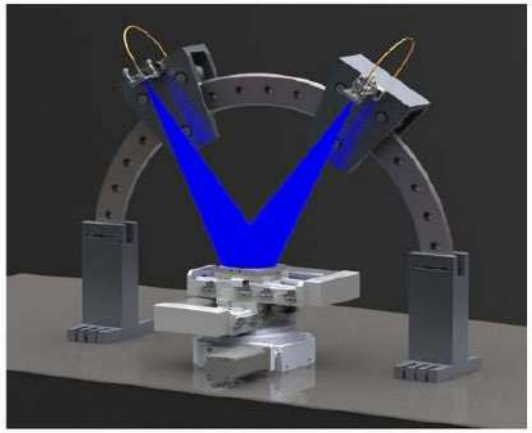
Source: www.toptica.com

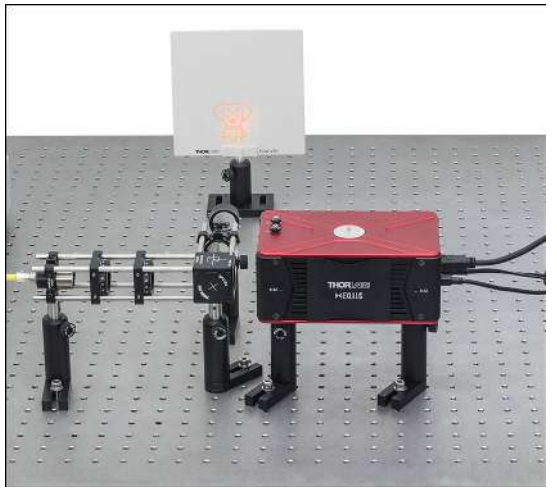
Laser systems:

- 405 nm cw laser for 1PL and LIL
- 780 nm femtosecond laser for 2PL
- Average output power of 1 W

Four writing modules:

- One photon laser lithography
- Two photon laser lithography
- Laser interference lithography
- Parallel writing module based on a spatial-light modulator





Source: www.thorlabs.com

OPTIMAL platform

Monitoring and feedback control modules

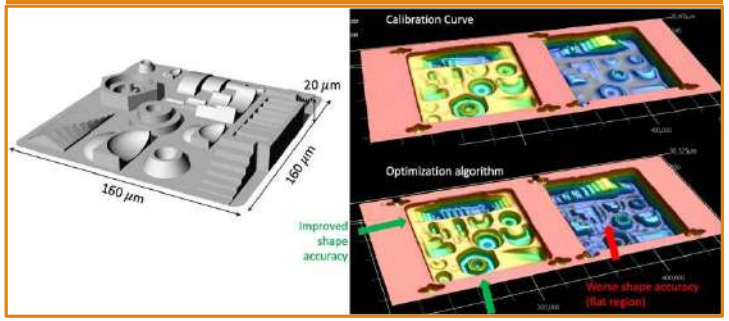
Vision system able to track objects:

- System calibration procedures as well as software modules for fast focus determination
- Specific cameras with the corresponding software controllable new lighting method for a better display of the surfaces.
- Innovative dark-field and diffractive imaging approaches for large-area surface testing
- The results is a vision subsystem targeting heterogeneity and sample defects.

Self-learning algorithms for optimization of process parameters:

- Based on neural network represent the physical process.
- Lead to an improvement in build accuracy compared to a contrast curve.
- Benchmark artefacts for efficient acquisition of data required for training self-learning algorithms.
- Expandable data and metadata libraries comprising all data
  - Will be made publicly available on the project website

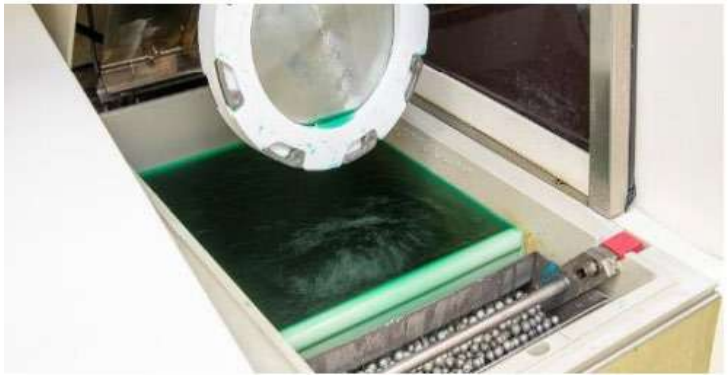
Self-learning algorithms



Use cases

The **OPTIMAL** platform will be validated through the manufacturing of master tools for **4** different use cases:

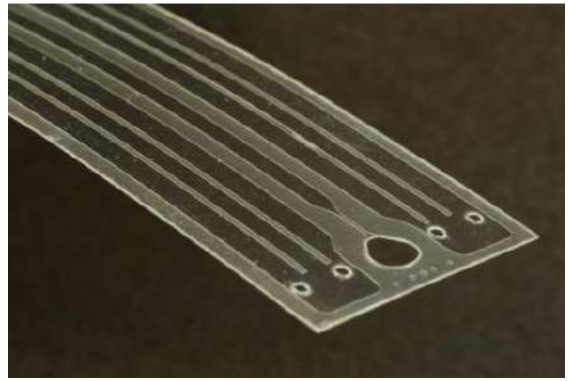
1. Full-polymer micro lenses for industrial optics.
2. Hierarchical multifunctional drag reduction riblet structures for aviation.
3. Free-form lens arrays for high-end virtual reality displays.
4. Microfluidic hierarchical structures for lab on chip medical devices.



1

2

3



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Thank you for your attention!

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