HEIDELBERG INSTRUMENTS

MPO 100: The Future of 3D Nano- and Micro-Lithography

28 May 2024
Benedikt Stender

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Heidelberg Instruments | Systems and Technology Pool

High-precision maskless aligner and laser lithography systems, for direct writing of 2D and 2.5D microstructures and for photomask production

Thermal Scanning Probe Lithography (t-SPL) for advanced nanofabrication

Maskless 3D Laser Lithography via Two-Photon Polymerization (TPP) for the fabrication of real 3D nano and microstructures

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MPO 100

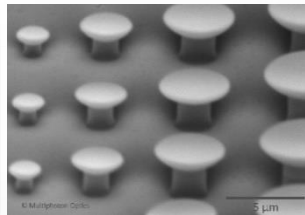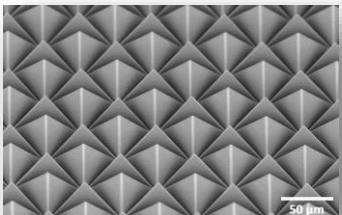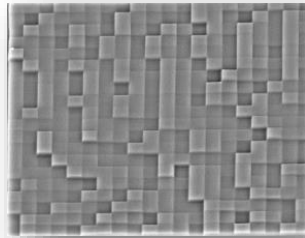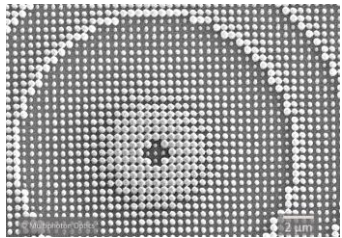**3D Nanoprinting** ← high resolution / high surface quality   **bridging the gap**   larger objects / high throughput → **3D Microprinting**
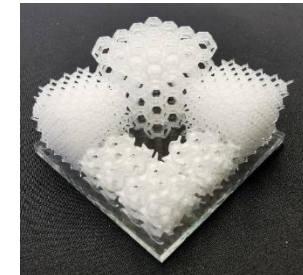
Applications:
Photonics, Microoptics, …

Applications:
µ-fluidics, µ-mechanics, Biomedical, …

MPO 100 enables…
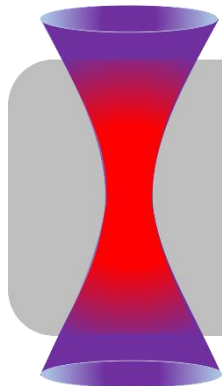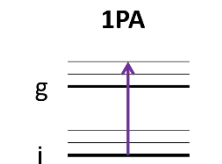
… 3D Lithography with feature sizes of 100 nm and optical surface quality below Ra = 10 nm

… 3D Microprinting of structures with a height of over 1 cm and maximum scan speeds ≥ 1000 mm/s

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Two-Photon Polymerization (TPP)

One-Photon absorption

1PA

$W \propto I$

Two-Photon absorption

2PA

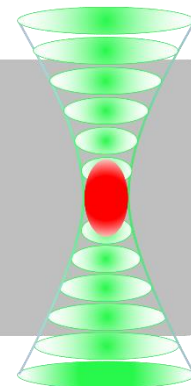$W \propto I^2$

regions of absorption

photoresist
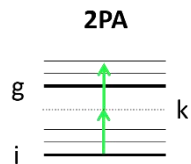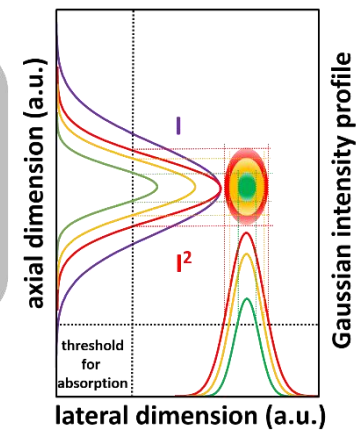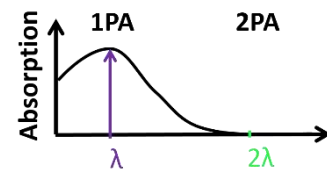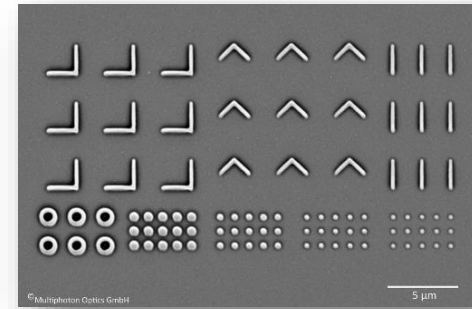
Tuning the Voxel size:
- Laser Power
- Optics
- Material
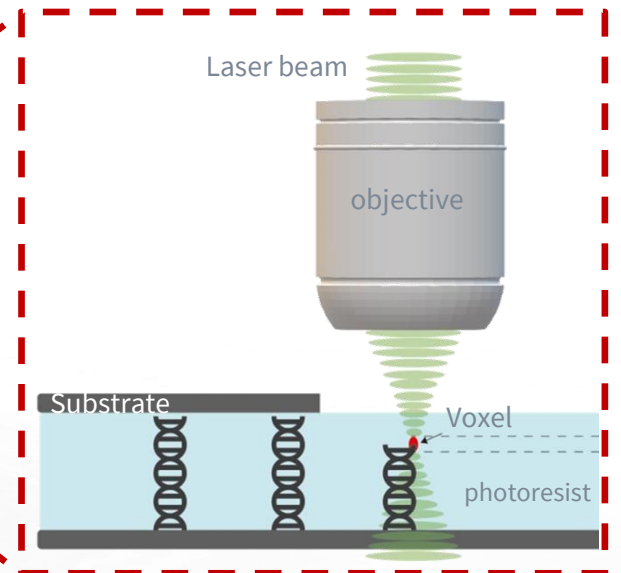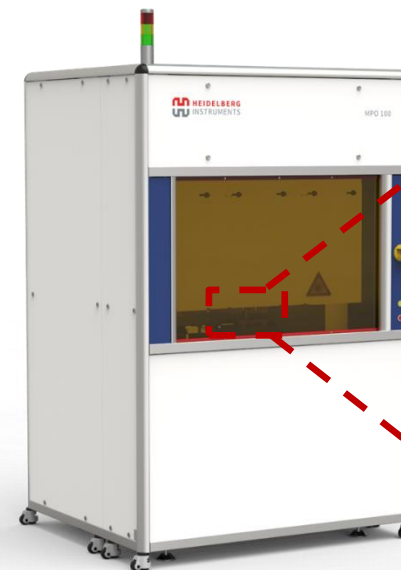
Laser beam

objective

Substrate

Voxel

photoresist

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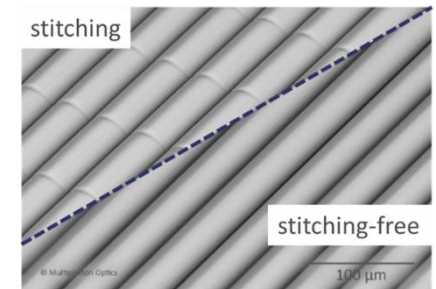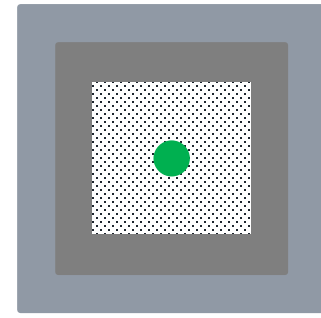
Scanning System – Fabrication Modes
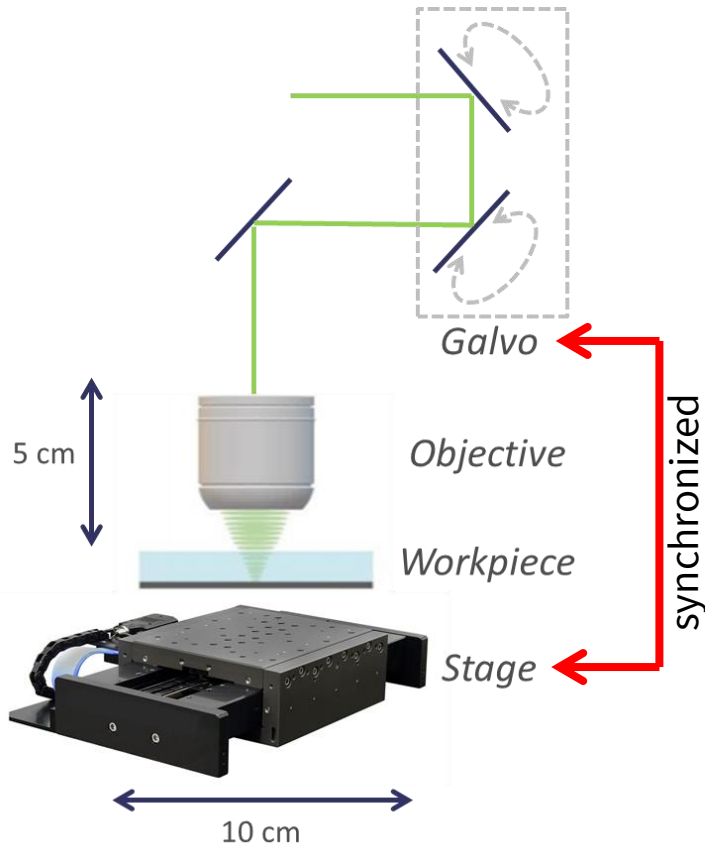
Galvo Mode
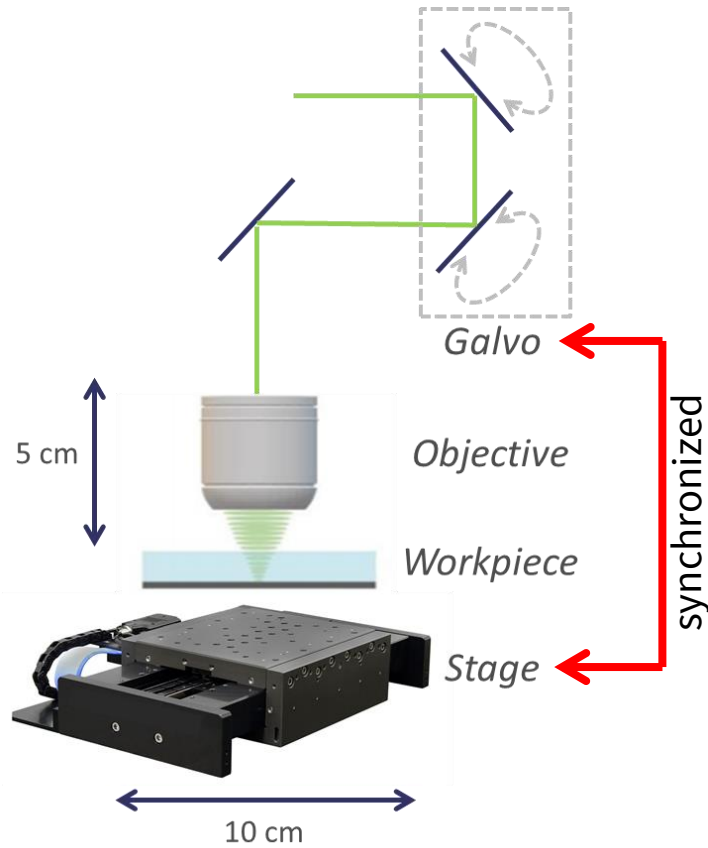Stage in center position
Scanning with galvo
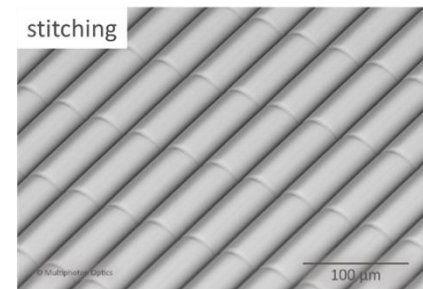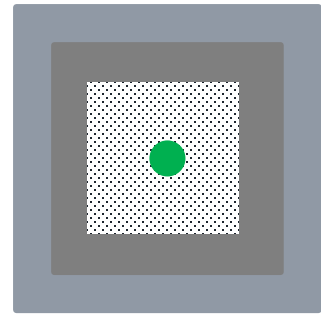
Stage Mode
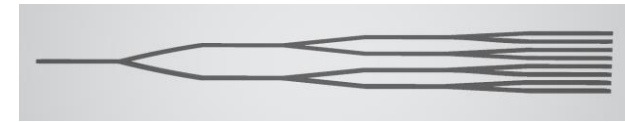Laser focus fixed
Scanning with stage
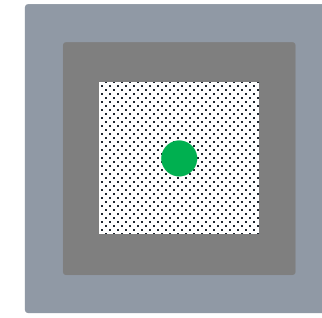
IFoV Mode
Stage continuously moving
Scanning with galvo
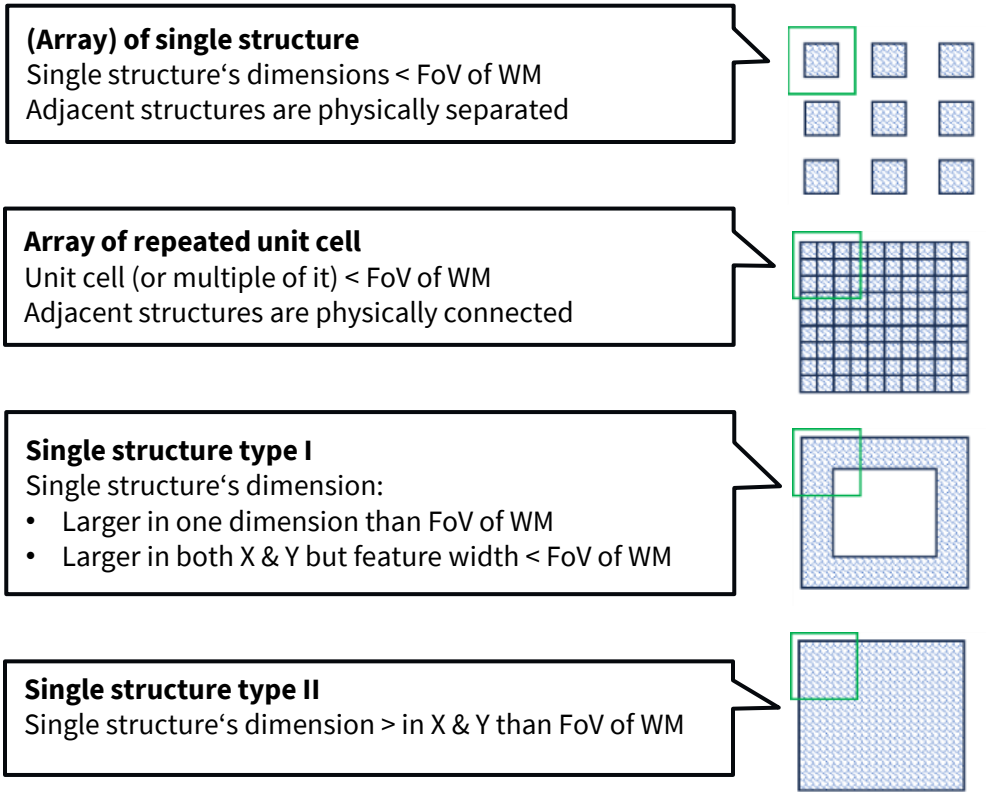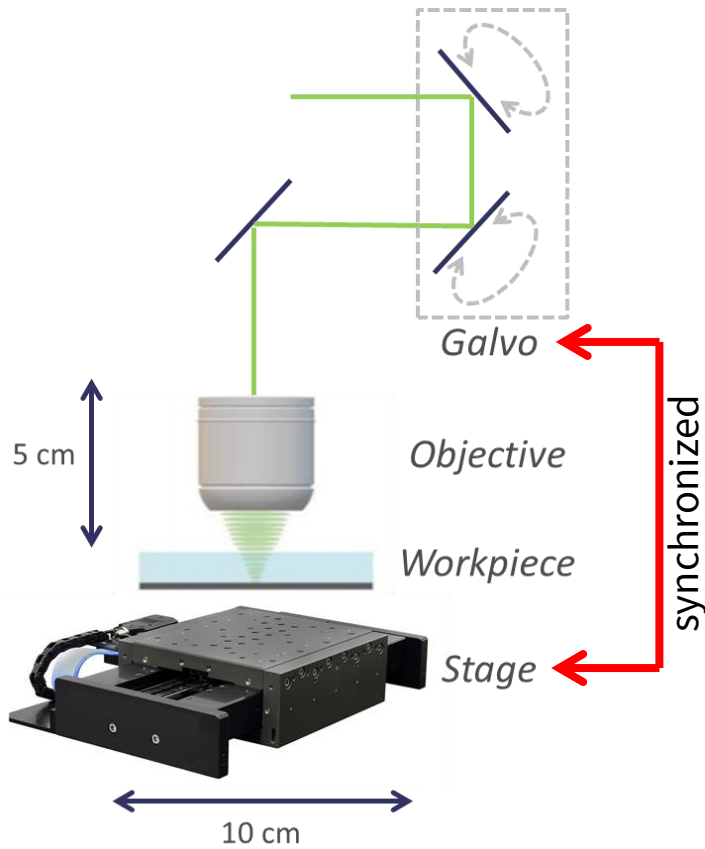
Scanning System – Fabrication Modes

Design

Galvo Mode & Stitching

20 µm
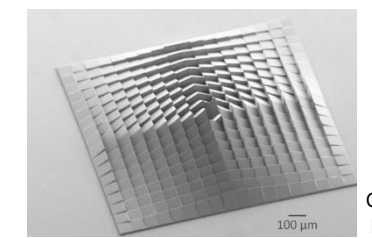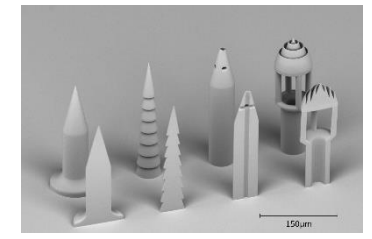
IFoV Mode & Stitching-free

20 µm

5 cm

Galvo

Objective

Workpiece

synchronized

Stage

10 cm

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Scanning System – Fabrication Modes

5 cm

10 cm

Galvo

Objective

Workpiece

Stage

synchronized

(Array) of single structure
Single structure's dimensions < FoV of WM
Adjacent structures are physically separated

Array of repeated unit cell
Unit cell (or multiple of it) < FoV of WM
Adjacent structures are physically connected

Single structure type I
Single structure's dimension:
- Larger in one dimension than FoV of WM
- Larger in both X & Y but feature width < FoV of WM
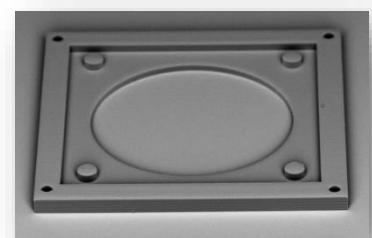
Single structure type II
Single structure's dimension > in X & Y than FoV of WM

☐ Field-of-View (FoV)   ▨ Structure / Unit Cell

Courtesy of Fraunhofer ISC

Design by Mimotec SA

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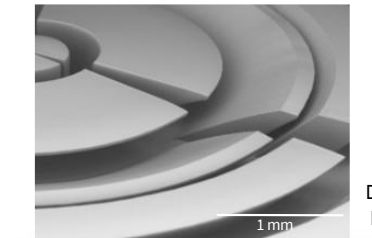
Scanning System – Fabrication Modes

(Array) of single structure
Single structure's dimensions < FoV of WM
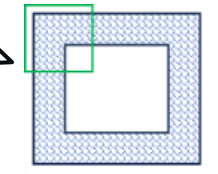Adjacent structures are physically separated

Array of repeated unit cell
Unit cell (or multiple of it) < FoV of WM
Adjacent structures are physically connected

Single structure type I
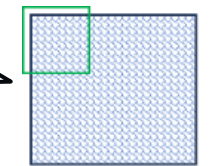Single structure's dimension:
- Larger in one dimension than FoV of WM
- Larger in both X & Y but feature width < FoV of WM

Single structure type II
Single structure's dimension > in X & Y than FoV of WM
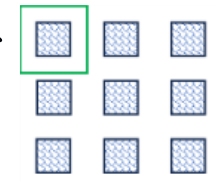
Galvo	Stage	IFoV
Stitching-free		
Stitching in tiles along X and Y	Stitching-free	Stitching in stripes along X or Y
Stitching in tiles along X and Y	Stitching-free	Stitching-free
Stitching in tiles along X and Y	Stitching-free	Stitching in stripes along X or Y

☐ Field-of-View (FoV)   ▨ Structure / Unit Cell

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Scanning System – Combination of Fabrication Modes
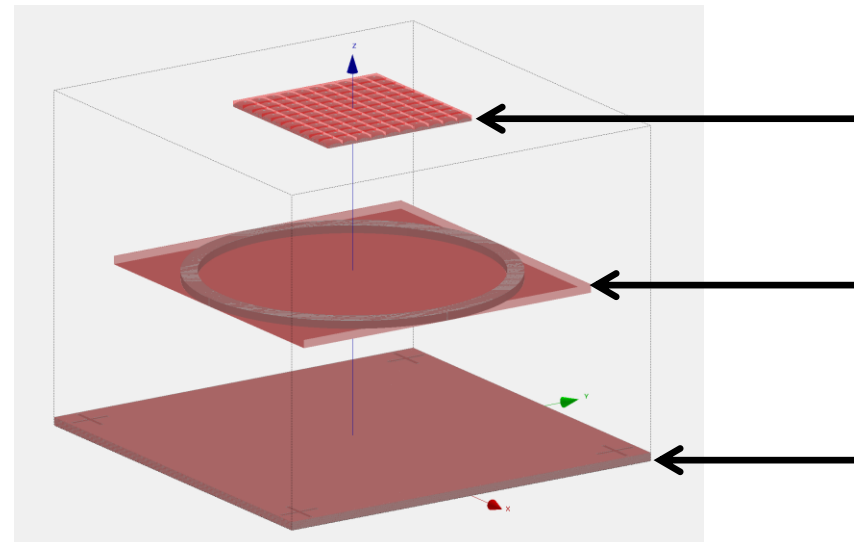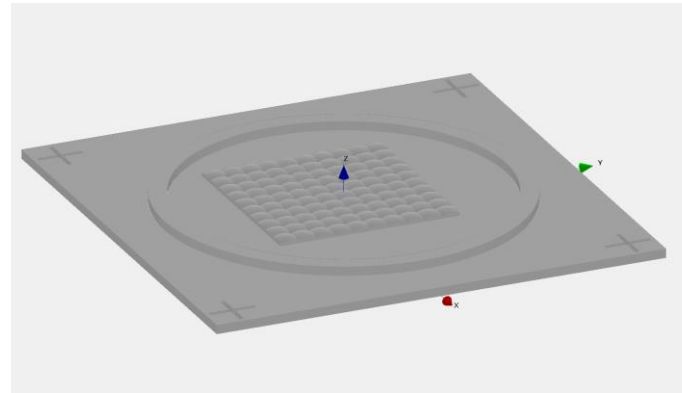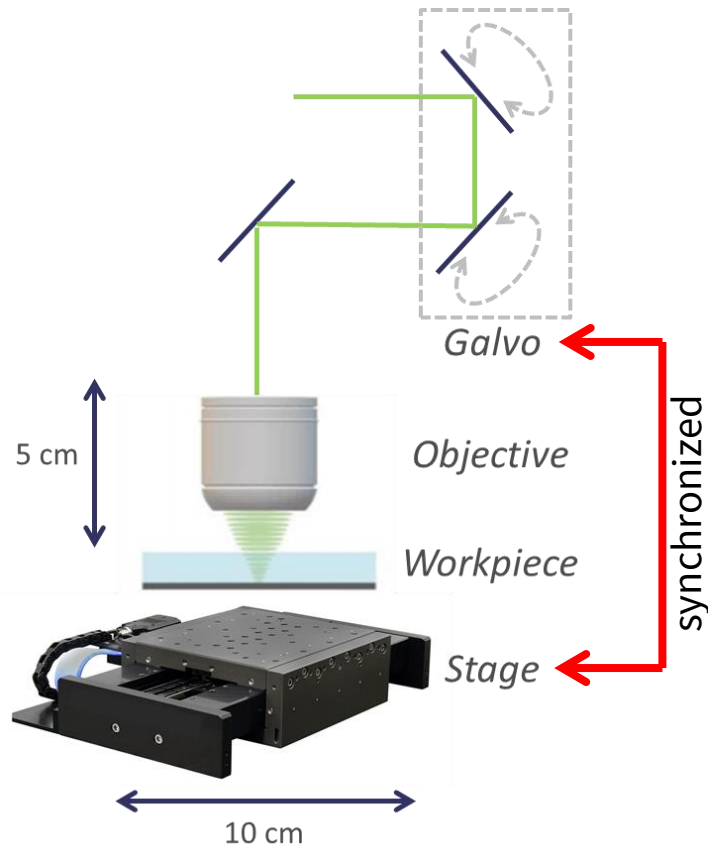
Complex Design

- Fabrication in one piece

  or

- Splitting to apply different fabrication modes
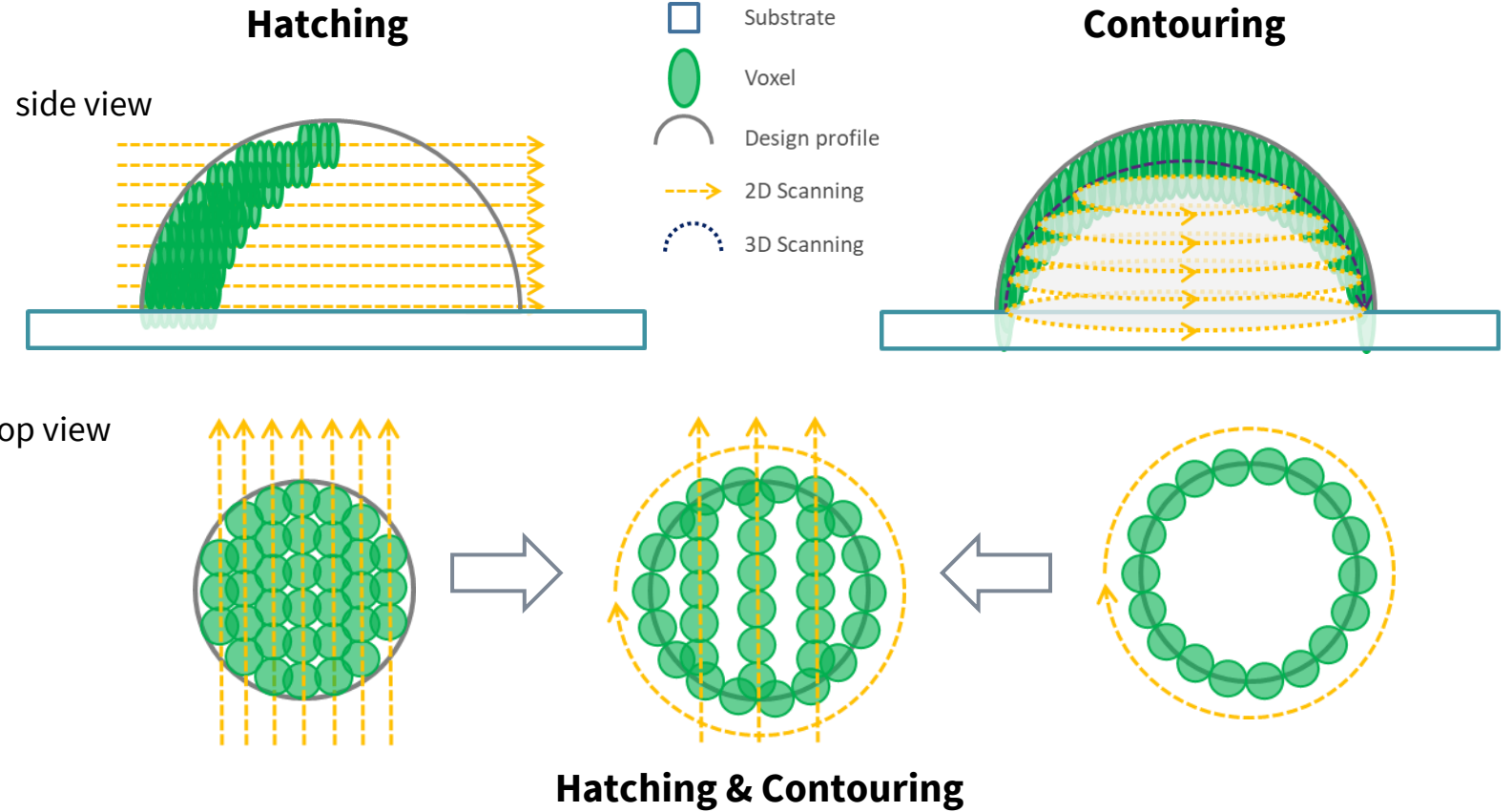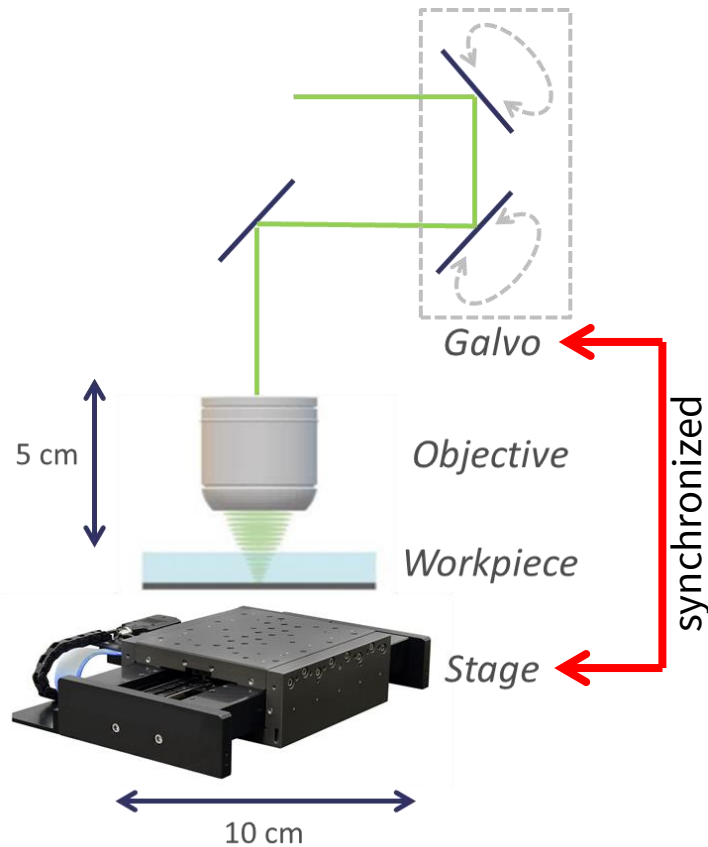
Galvo Mode
Hatching and Stitching in tiles

IFoV Mode
Hatching and stitching-free

Stage Mode
Hatching and stitching-free

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Scanning System – Scan Strategies

Hatching: The volume of a design is scanned (hatched) consecutively in layers (slices)
Contouring: The shell of a design is contoured laterally/vertically in consecutive slices
Hatching & Contouring: Both shell and volume of a design are exposed

Scanning System – Scan Strategies
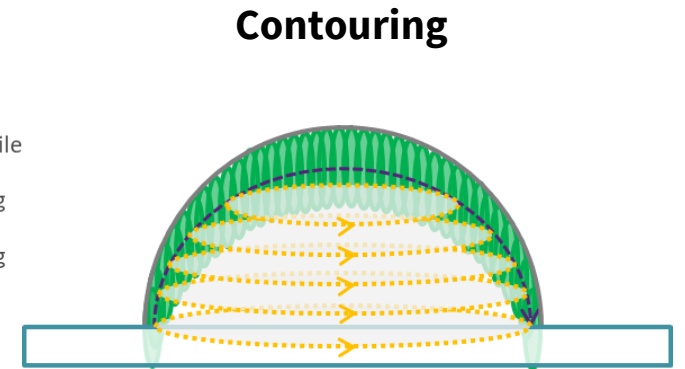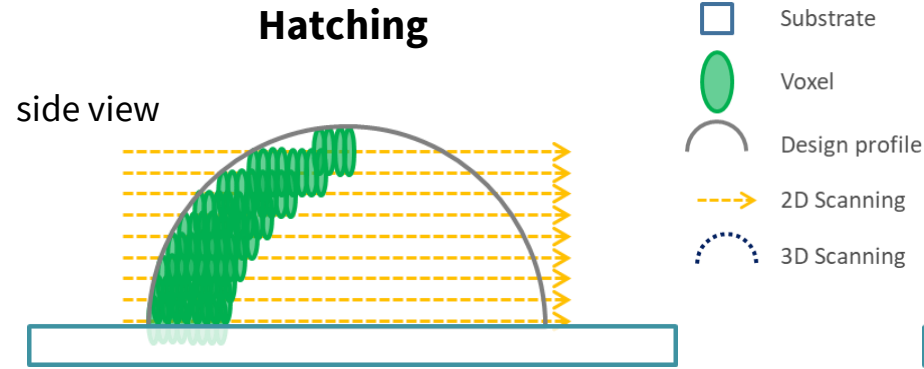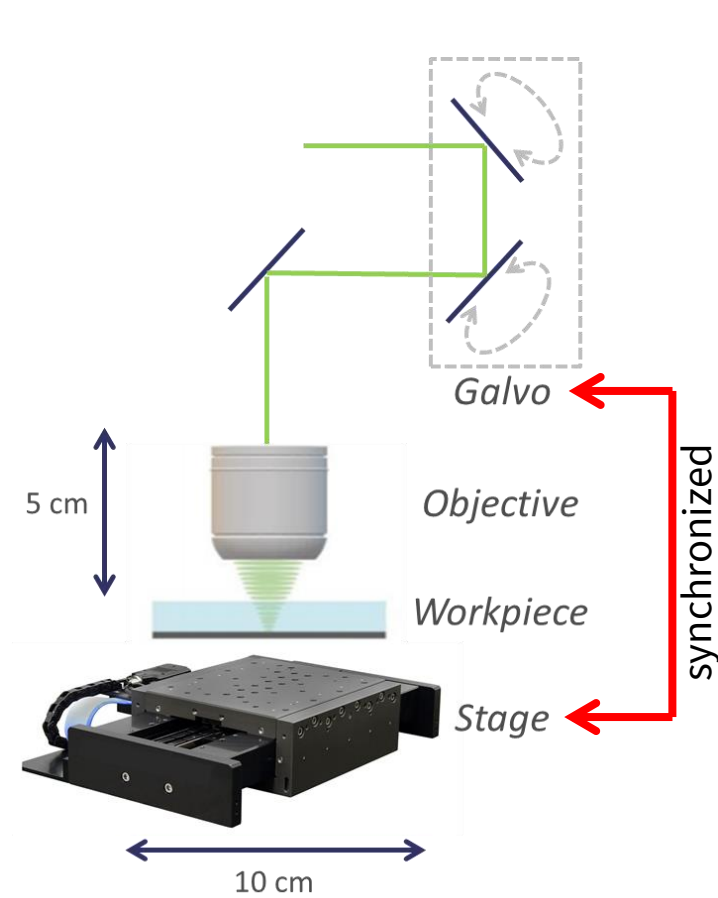
Scanning System – Scan Strategies
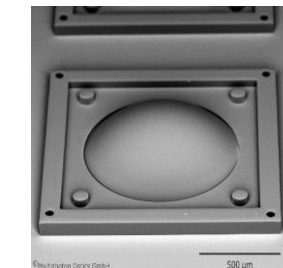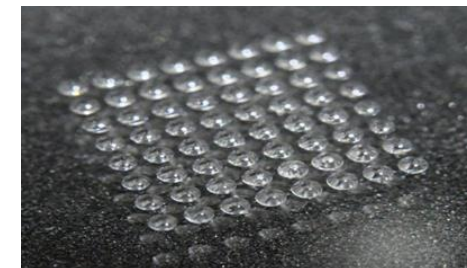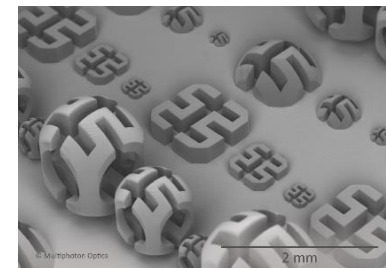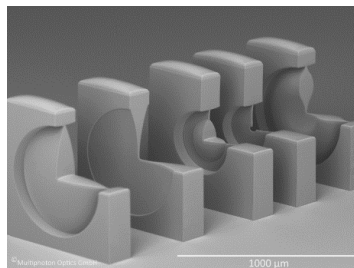
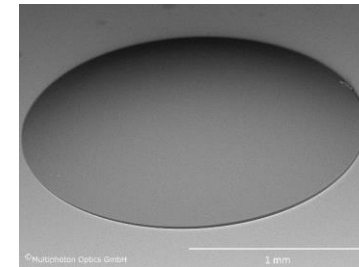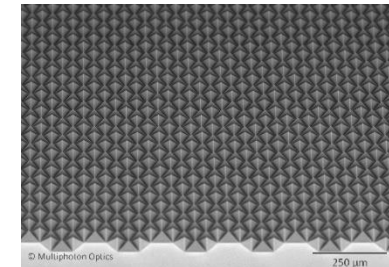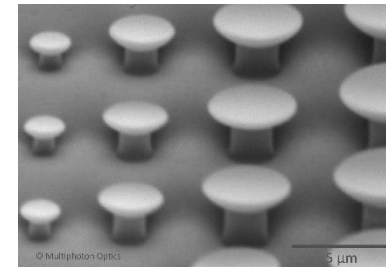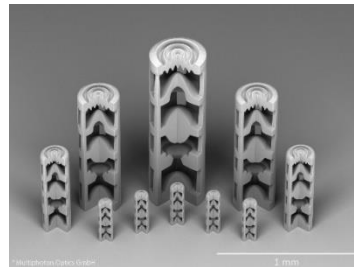**Hatching**
constant laser power

side view

Substrate

Voxel

Design profile

2D Scanning

3D Scanning

5 cm

Objective

Workpiece

Stage

Galvo

synchronized

10 cm
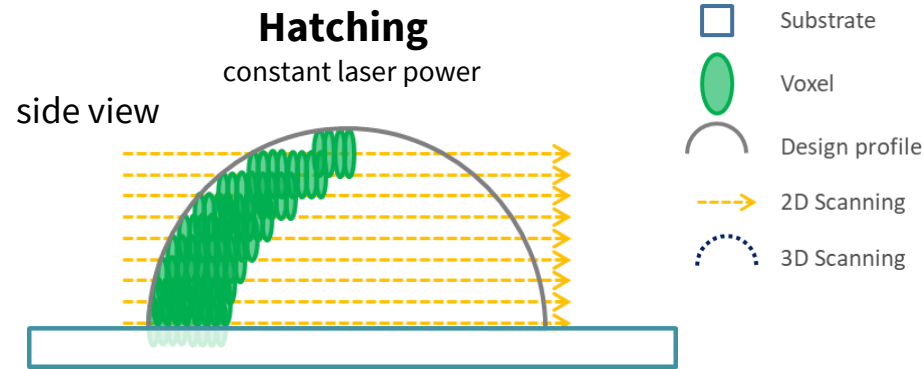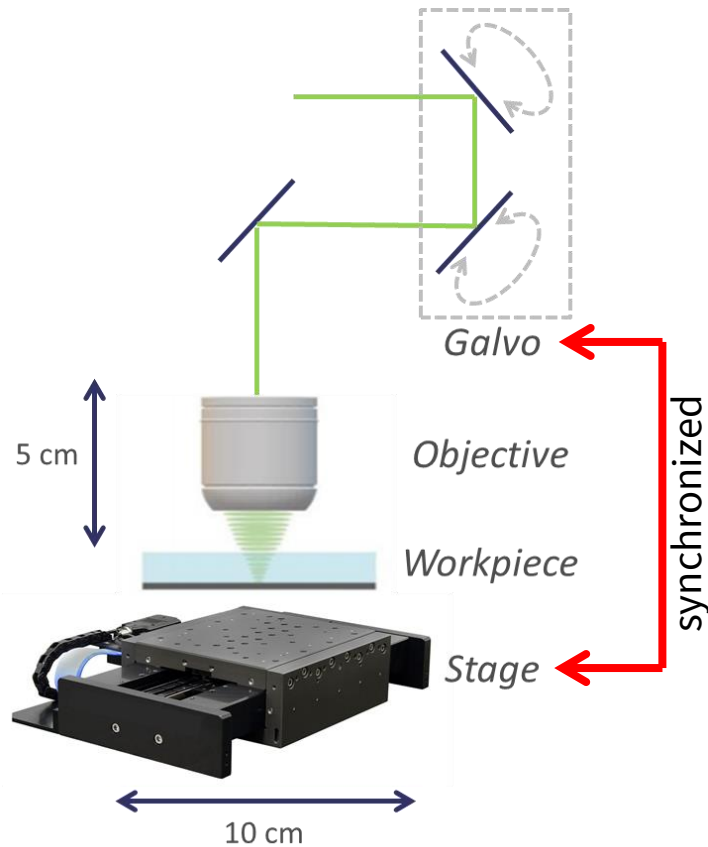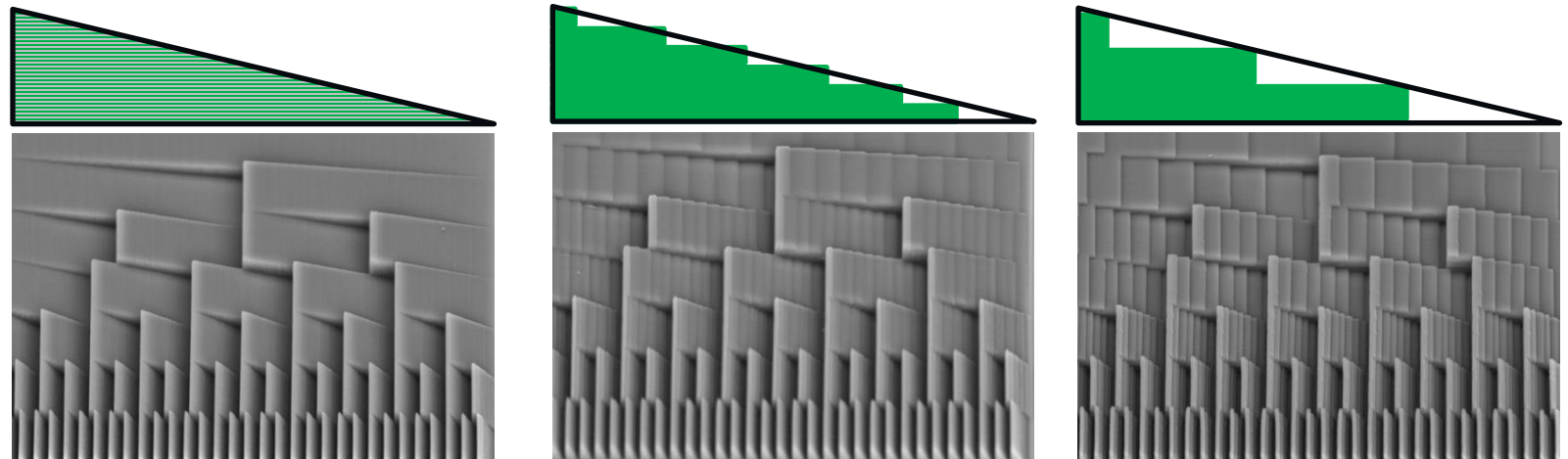
+ Fab time decreases
- Fab quality decreases

Decreasing
No. of layers

Scanning System – Scan Strategies

AOM

Galvo

5 cm

Objective

Workpiece

Stage

10 cm

synchronized

Hatching
constant laser power

side view

+ Fab time decreases
- Fab quality decreases

Decreasing
No. of layers

Substrate
Voxel
Design profile
2D Scanning
3D Scanning

1PA   2PA

$W \propto I$ $W \propto I^2$

regions of absorption
photoresist

Scanning System – Scan Strategies

AOM

Galvo

5 cm

Objective

Workpiece

synchronized

Stage

10 cm

Hatching
constant laser power

side view

Substrate
Voxel
Design profile
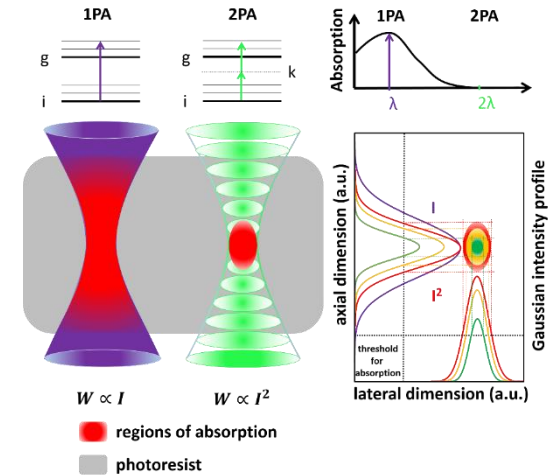2D Scanning
3D Scanning

Voxel Tuning
modulation of laser power

+ Fab time decreases
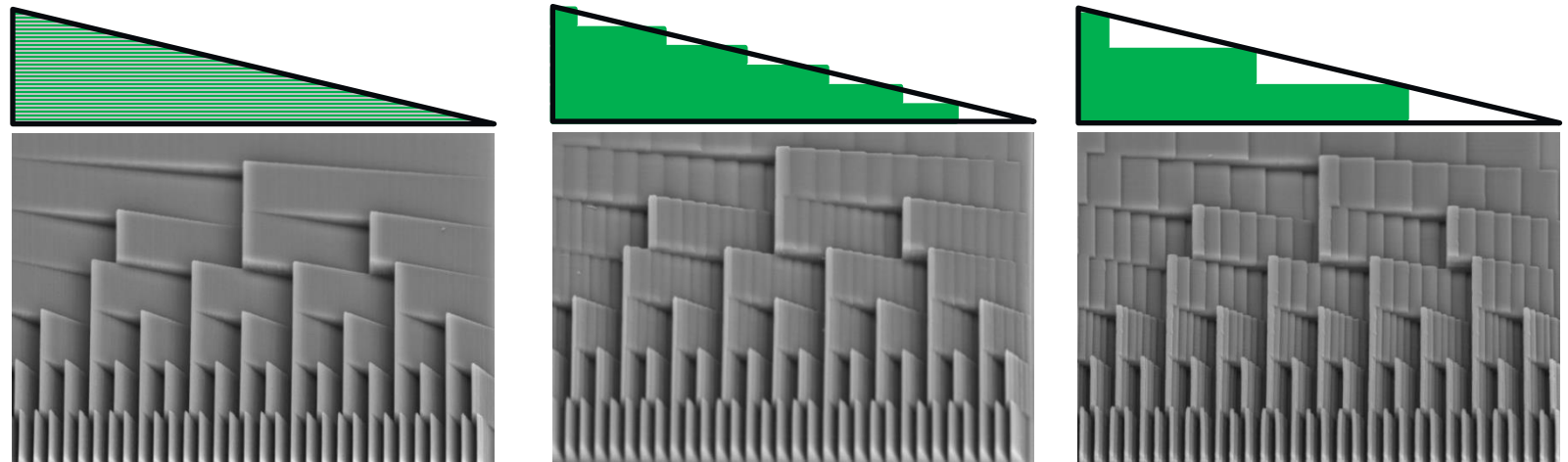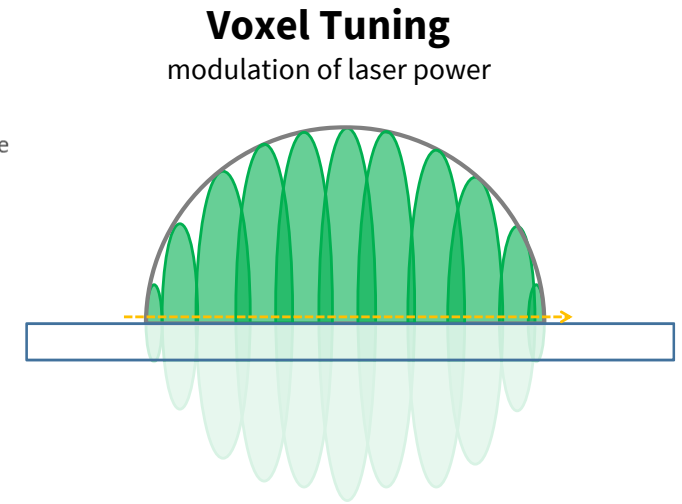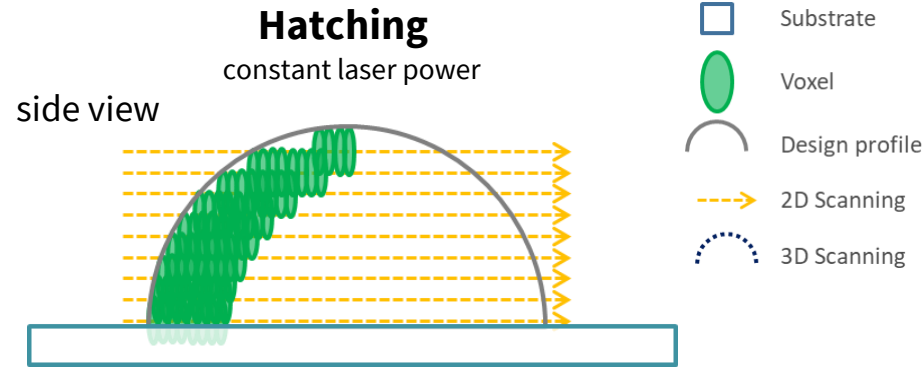- Fab quality decreases

Decreasing
No. of layers

Voxel Tuning off

Scanning System – Scan Strategies

AOM

Galvo

Objective

5 cm

Workpiece

Stage

10 cm

synchronized

Hatching
constant laser power

side view

Voxel Tuning
modulation of laser power
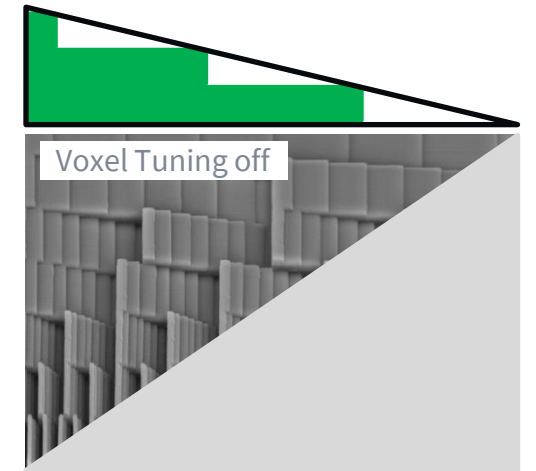
☐ Substrate
⬭ Voxel
⌒ Design profile
→ 2D Scanning
··· 3D Scanning

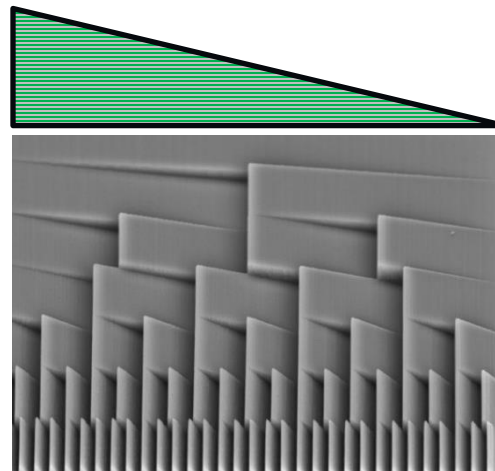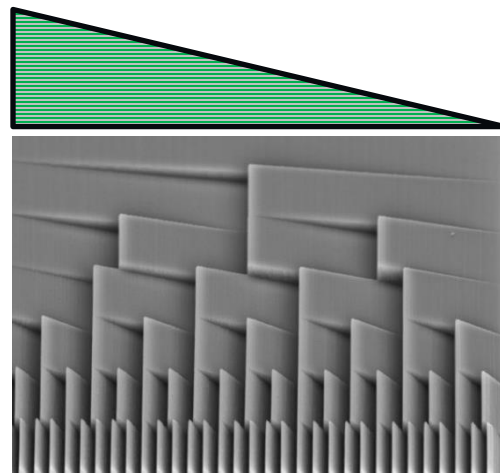+ Fab time decreases
- Fab quality decreases

Decreasing
No. of layers

+ Fab time decreases
+ Fab quality high

Voxel Tuning off

Voxel Tuning on

Voxel Tuning specs:
- 10 MHz modulation rate
- 10 nm grid at full speed
- 5x-50x throughput
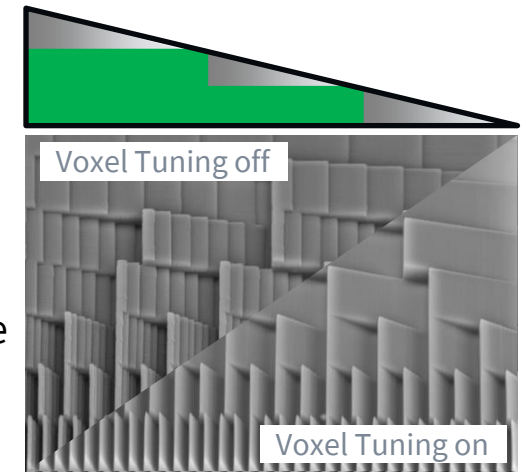
THANK YOU!

HEIDELBERG INSTRUMENTS
MIKROTECHNIK GMBH
MITTELGEWANNWEG 27
69123 HEIDELBERG
GERMANY
PHONE +49 6221 728899-0

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