

Martin Osbild
23.10.2023

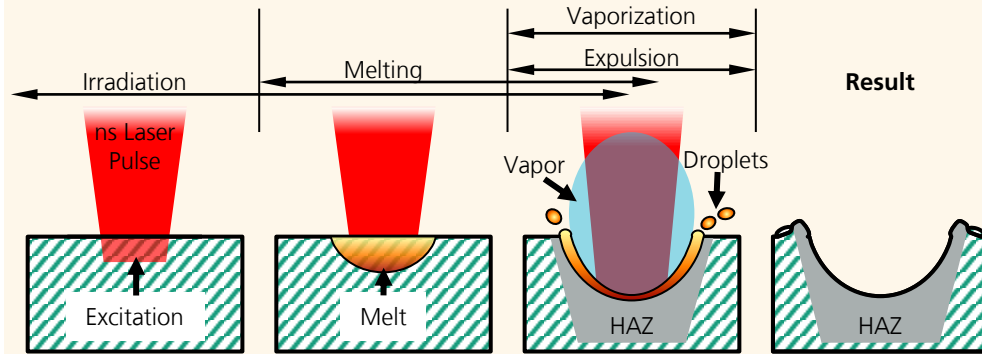
High-throughput Micro-machining using Ultrashort Pulsed Lasers



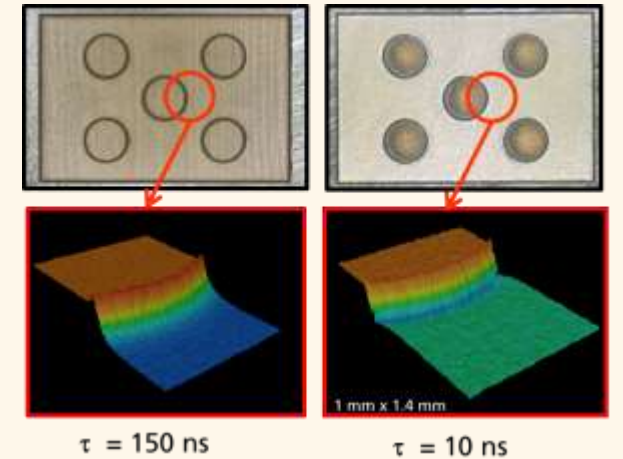
Introducing our machining tool

Why ultrafast lasers?

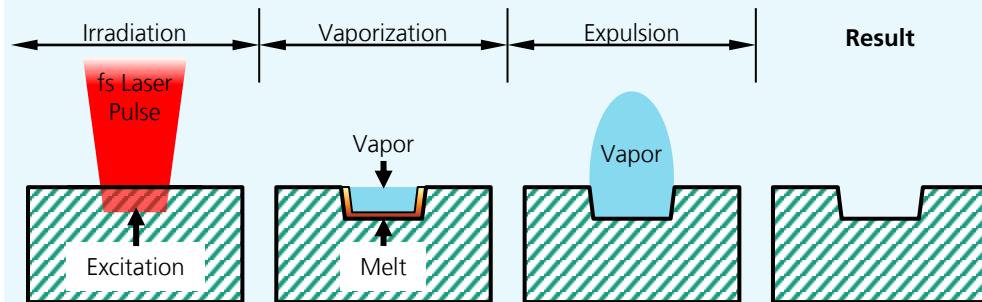
Nanosecond pulse duration



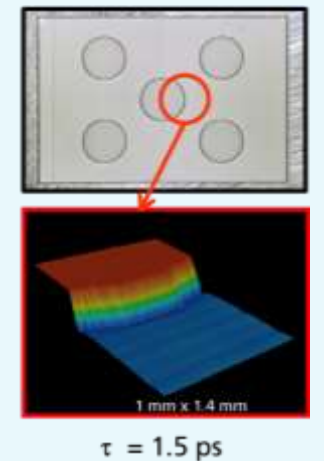
- ▲ High removal rate
- ▼ Low precision due to melt-dominated ablation
- ▼ Debris and burrs
- ▼ Pronounced heat affected zone



Pulse duration <10 ps



- ▲ High precision due to sublimation-dominated ablation
- ▲ Minimal thermal impact
- ▲ Processing of practically all materials due to non-linear absorption
- ▼ Relatively low removal rate



Group Micro and Nano Structuring

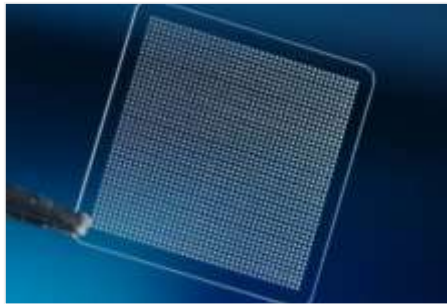
Team structure

Drilling



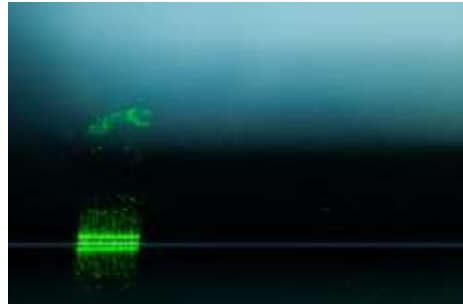
- Cooling holes for turbomachinery
- Drilling of embossing tools
- CFRP-Preforms
- Precision drilling

Transparent Materials



- USP processing of transparent materials
- Pump & probe analysis
- Integrated optics
- SLE
- Beam shaping

Thin film ablation



- Selective thin film ablation
- Interference patterning
- Surface structuring and functionalization

3D-Structuring



- Structuring of embossing tools
- High-power USP material processing
- Ablation of compound materials
- Scaling approaches (beam splitting and shaping)

Semiconductor

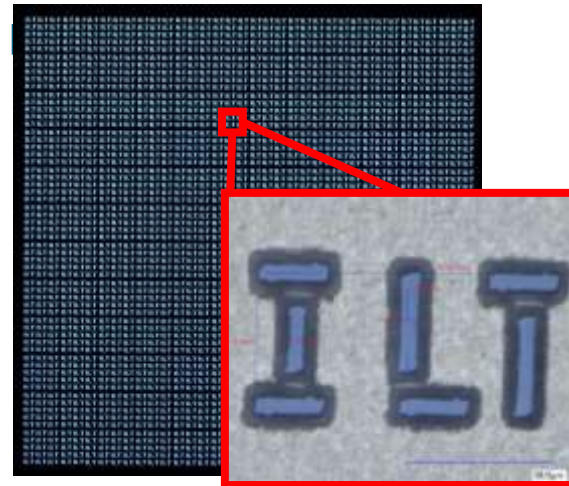
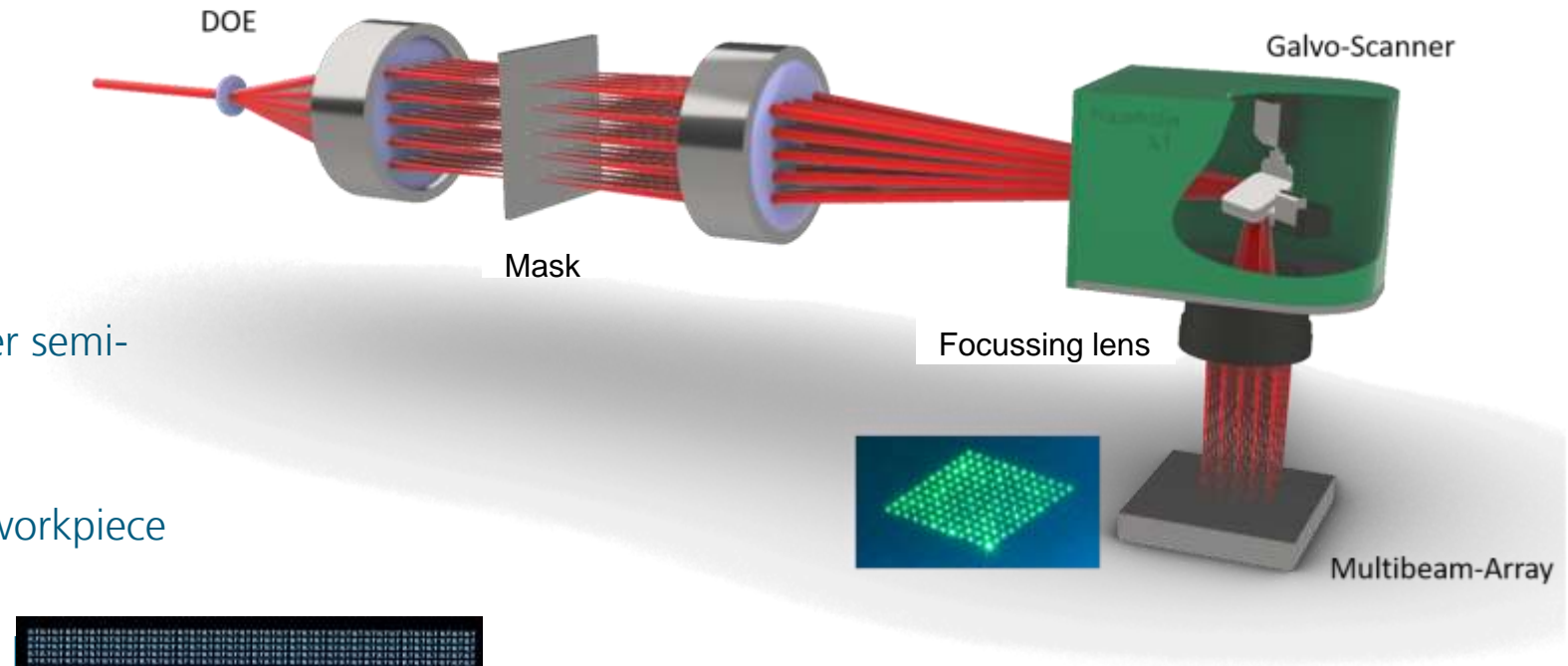


- 3D-Lithography
- Laser-Lift-Off
- Dicing
- Trenching

Multibeam processing

Fundamentals

- Split high pulse energy into numerous partial beams (>100 possible)
- Beam splitting achieved with DOEs or other semi-transparent mirrors
- **Static** multibeam processing
 - Whole bundle of beams is guided over workpiece simultaneously
 - Suitable for strictly periodic structures or processing of multiple workpieces
- **Flexible** multibeam processing
 - Each beamlet can be individually modulated
 - Modulation achieved with external AOMs



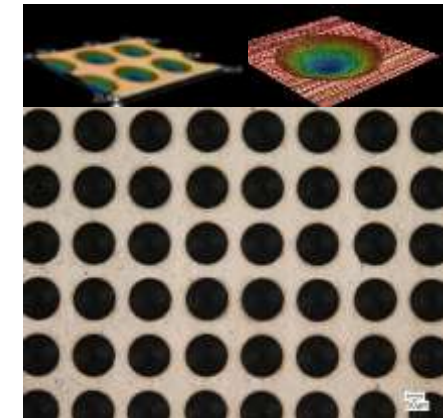
Dimensions

Gap width:

5 μm

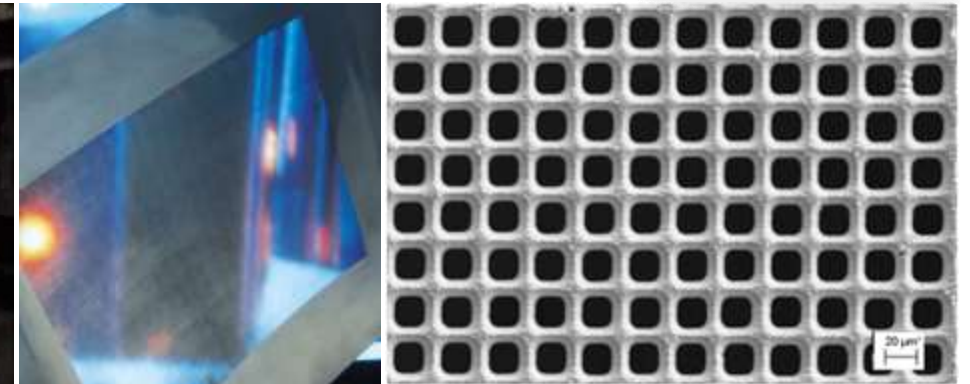
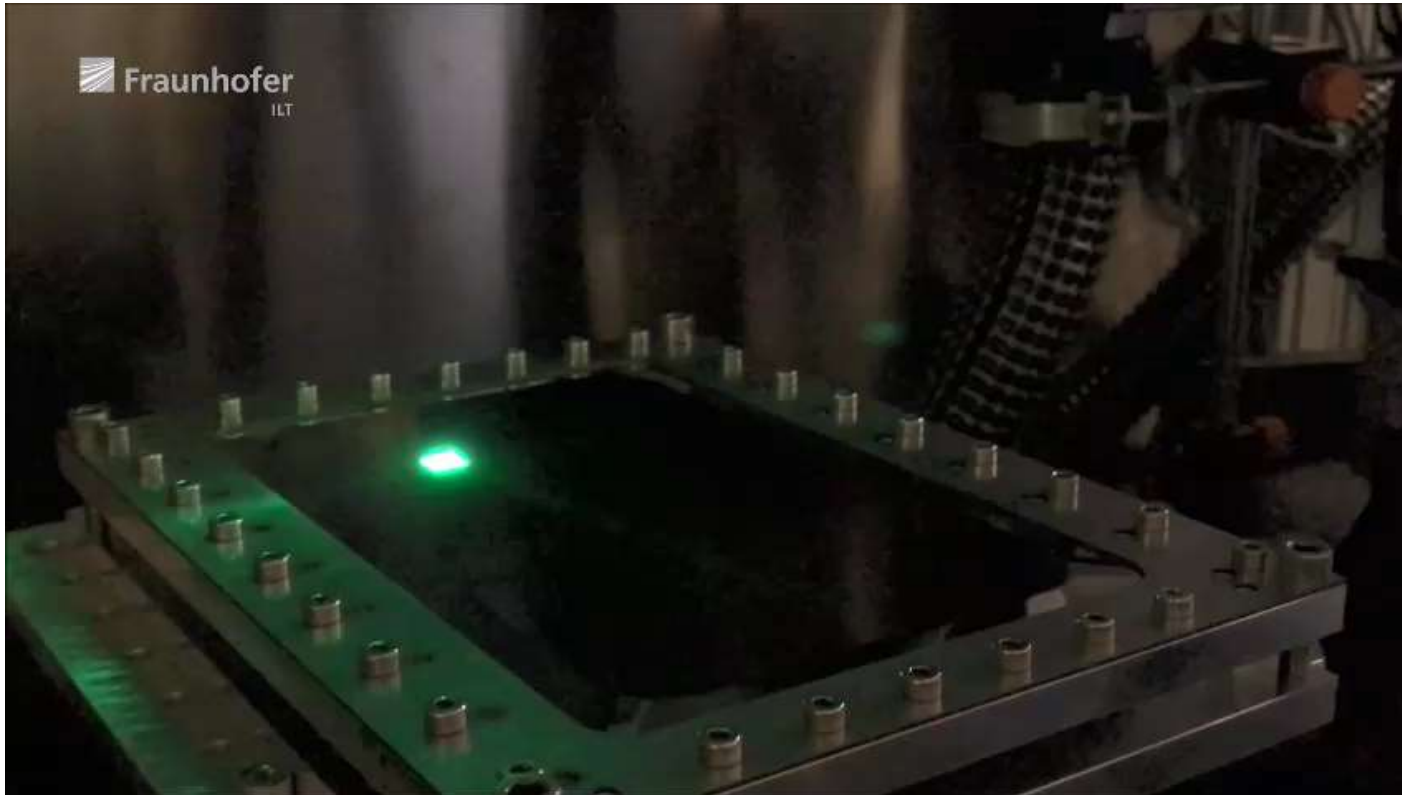
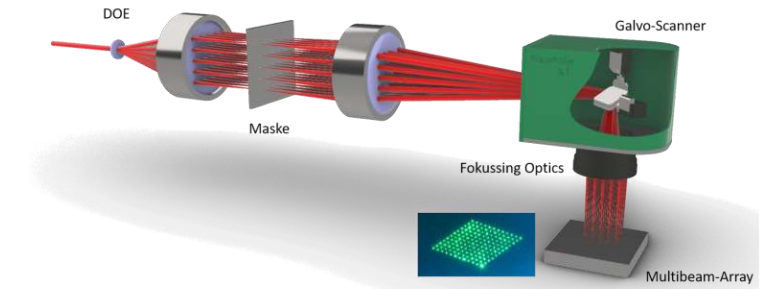
Bridge width:

5 μm



Static multibeam processing

Scanner-based high-throughput drilling with >100 beams

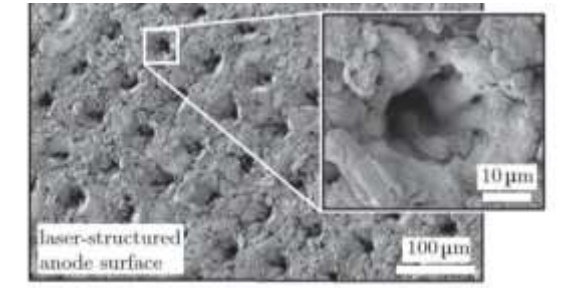
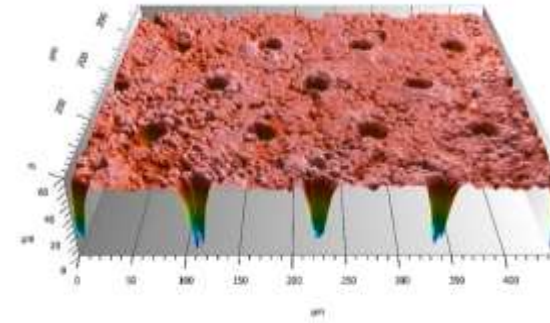


- 20000 holes per second possible
- Shaped holes possible
- Applications:
 - Filters
 - Atomizers
 - Masks

Static multibeam processing

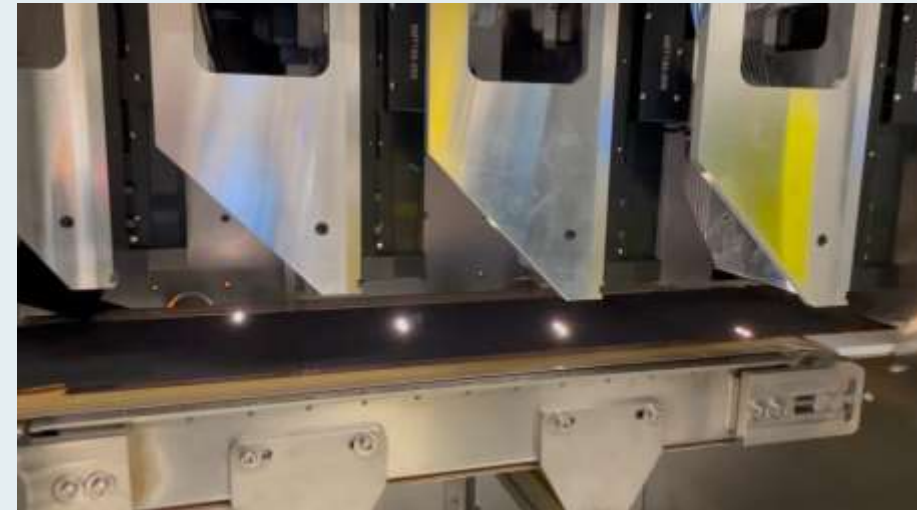
USP-structuring in a continuous production line (1)

- Benchmarking productivity for battery production



Multibeam multiscanner module

- High-power ultrafast laser (160 W, 1 mJ)
- 4 scanners with 6 beamlets for each scanner (1 pulse → 24 pulses)
- Structuring band material of 250 mm width

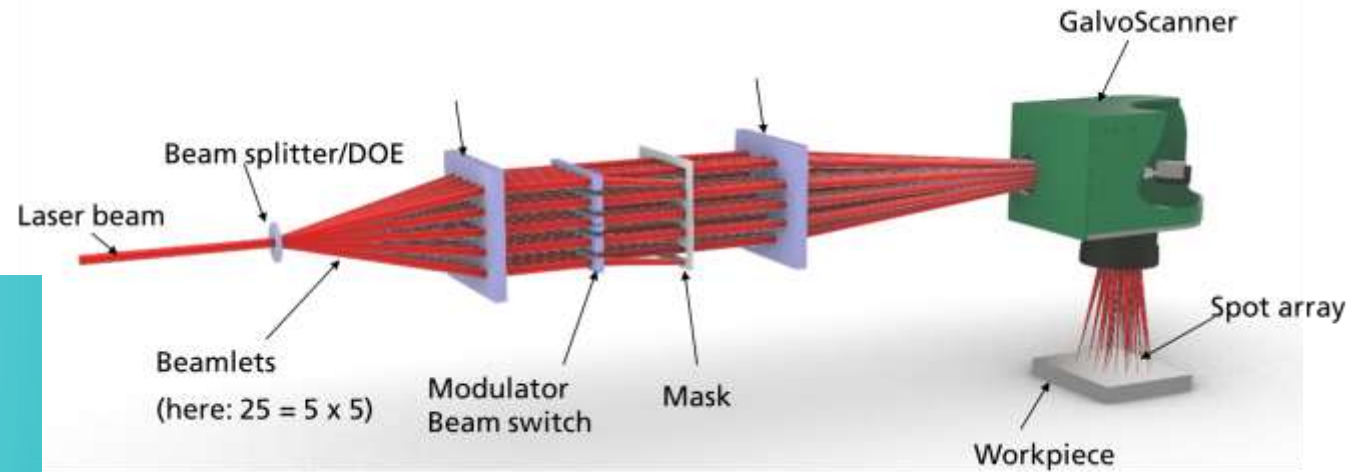


Flexible multibeam processing

MultiFlex project (2019–2023) (1)



- Array of 64 individually switchable beamlets
- Scan field correction for each beamlet
- FPGA based control system
- Online process monitoring
- Using 650 kW average laser power
- Large area surface structuring
- Throughput increase by 1-2 orders of magnitude



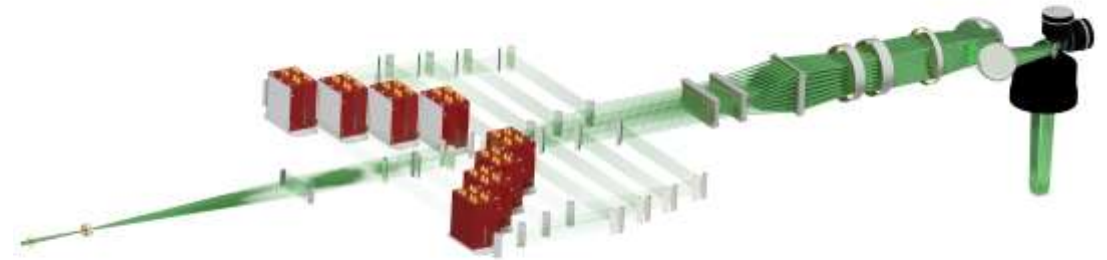
Flexible multibeam processing

MultiFlex project (2019–2023) (2)

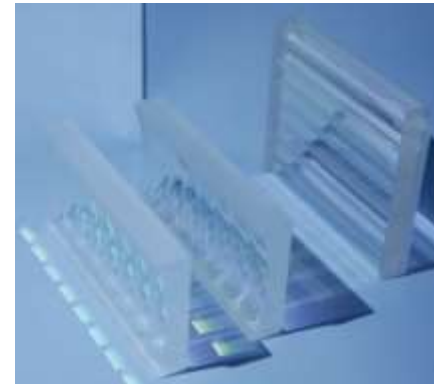
Delivery and assembly of Multiflex machine
in April 2023



Beam path



Prism stacks



Optical table in machine



Flexible multibeam processing

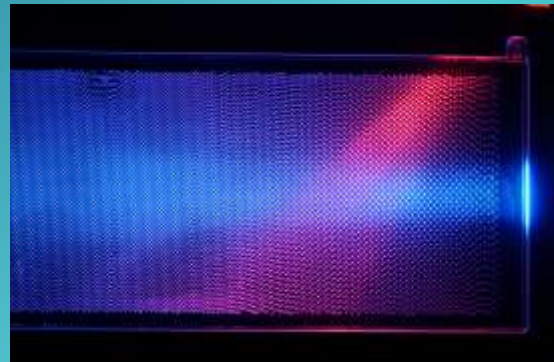
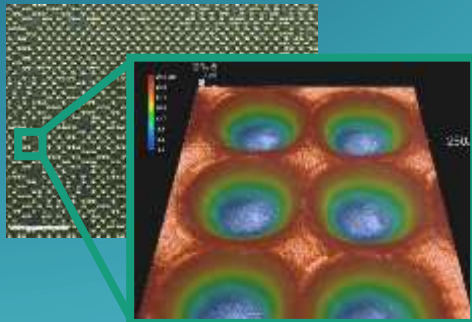
MultiFlex project (2019–2023) (3)

Current status

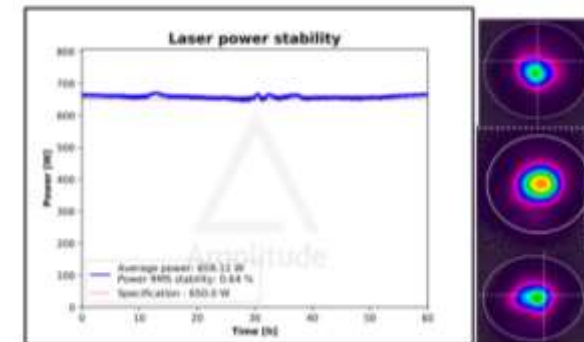
- Alignment of 64 beams ongoing
- Calibration of AOM drivers ongoing

Coming soon

- Tests on use-case: injection molding tool insert with non-periodic micro-lens array for automotive backlighting
- Application lab at ILT



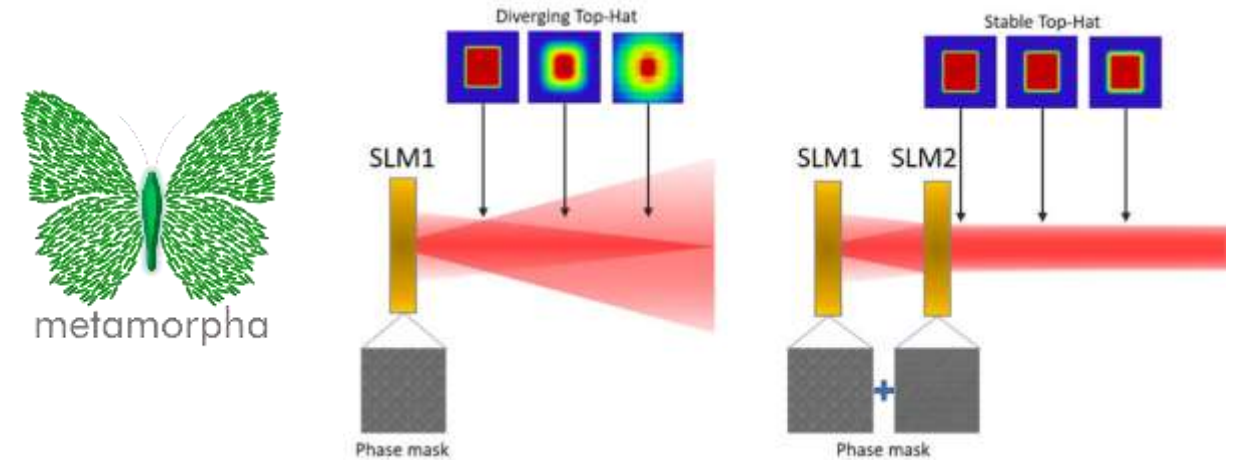
Synchronized 1x8 beam array



Flexible multibeam processing

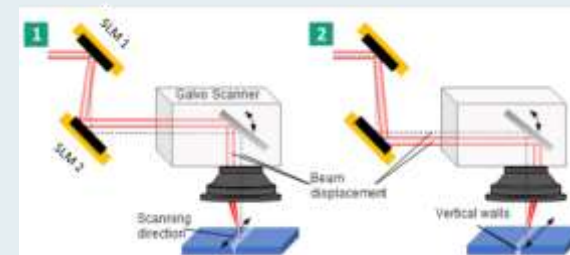
Metamorphosis project (2022–2026) (1)

- Substitution of conventional “dirty” manufacturing processes
- Arbitrary beam shaping with 2 cascaded SLMs
- Module compatible with 3/5-axis and cylinder structuring setups
- 3D sensor for individualized processes
- Machine-learning algorithms
- Realtime monitoring and closed-loop control for defect-free production
- Re-manufacturing of worn tools



Vertical wall angles

By manipulation of incidence angle



“Optical stamping”

Beam profile = final contour



Flexible multibeam processing

Metamorpho project (2022–2026) (3)

Approaches for productivity scaling

- Beam splitting
- Adapted dynamic size of focus spot
- Optical stamping
- Realtime monitoring and closed-loop control for defect-free production
- USP process chains (ablation+cleaning+polishing)
- Re-manufacturing of worn tools
- Modules can be parallelized



Carbide punch machined
in USP process chain



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