ULTRASHORT PULSED LASER PROCESSING AT 1 KILOWATT USING A FLEXIBLE MULTI BEAM APPROACH

MultiFlex

Forum “Intelligent Laser-Based Manufacturing in Europe”

Laser WORLD of PHOTONICS 2019, Munich

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Fraunhofer ILT · OPTO-ELECTRONIC · Amplitude · lasea PRECISION LASER SOLUTIONS · TOS Lehrstuhl für Technologie Optischer Systeme · lasea ADVANCED OPTICAL SYSTEMS

PHOTONICS 21

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AGENDA

1 The MultiFlex Project

2 MultiFlex in the context of Industry 4.0 and Digitalization

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1 **The MultiFlex Project**

2 **MultiFlex in the context of Industry 4.0 and Digitalization**

The MultiFlex Project

OBJECTIVE:

High Speed Ultrashort Pulsed Laser Processing Using Kilowatt Laser Power and Individually Modulated Multi-Beams

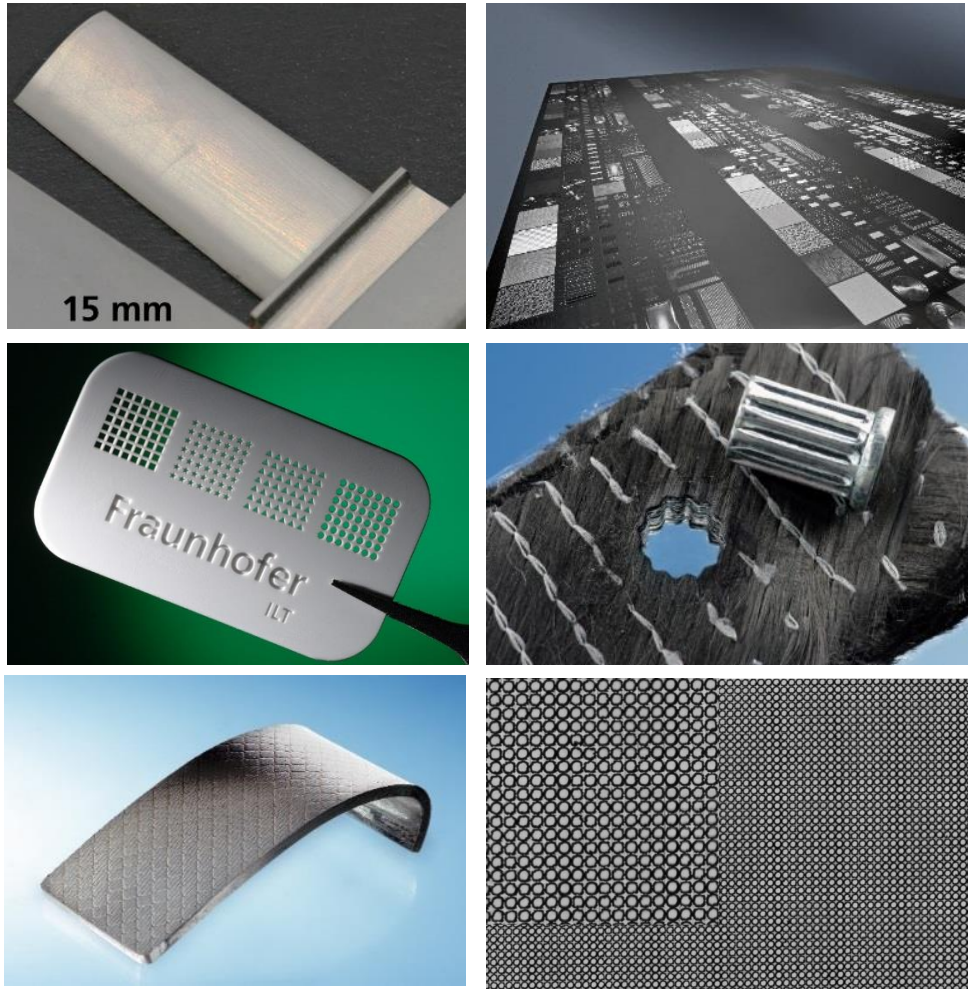
Why **ultrashort** pulses?

Why **kilowatt** average power?

Why individually modulated **Multi-Beams**?

Why ultrashort pulses?

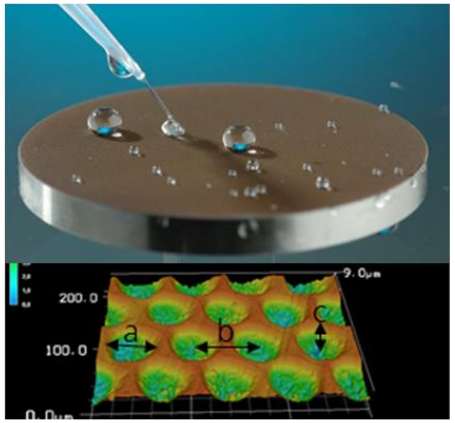
- Ultrafast Lasers
  - Pulse duration < 10 ps
    → MutliFlex: < 1 ps
  - Negligible thermal load
  - Highly precise
  - Nearly all kind of materials
  - Non-contact processing
  - Wear-free tool
  - Truly digital process



Source: ILT

Applications of ultrafast laser structuring

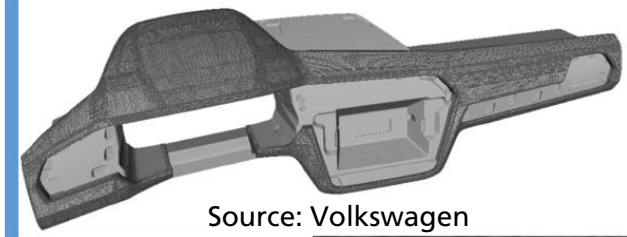
Structuring of functional surfaces



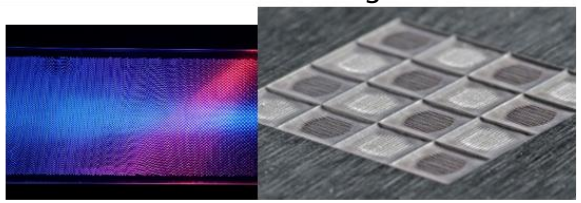
Source: ILT

- Self cleaning surfaces
- Friction reduction
- Anti-Icing
- Antibacterial surfaces
- Absorption enhancement

Structuring of molds and tools



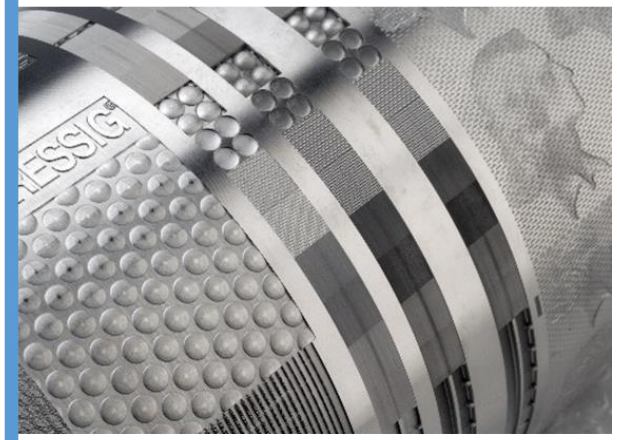
Source: Volkswagen



Source: ILT

- Design structures
- Haptic
- Illumination light guides
- Micro cavities

Structuring for embossing and printing applications

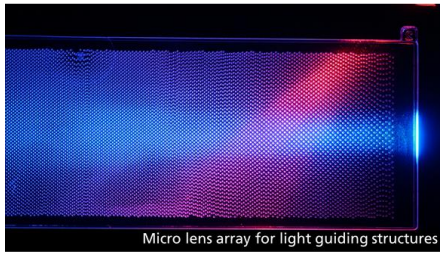


Source: ILT

- Printed electronics
- Security features
- Micro embossing
- Printing

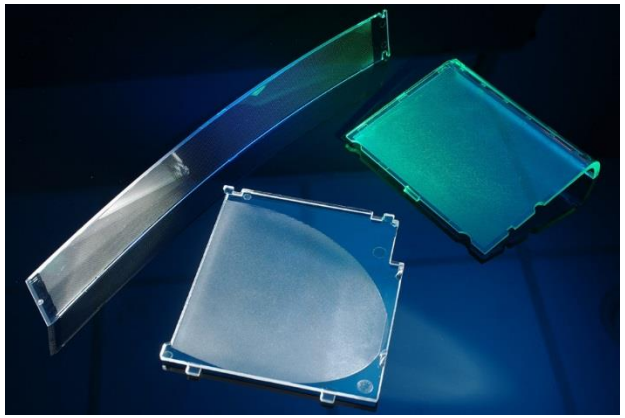
Focus of MultiFlex

Use Case: Light Guiding by Micro Injection moulded Lens Arrays

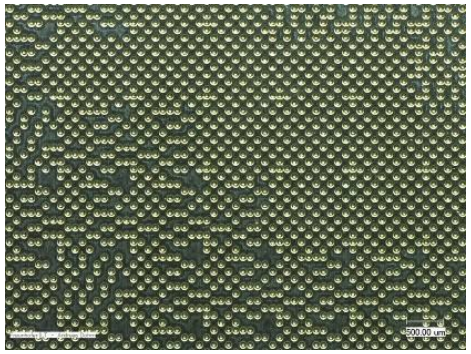


Homogenous illumination by scattering within light guide
Source: ILT

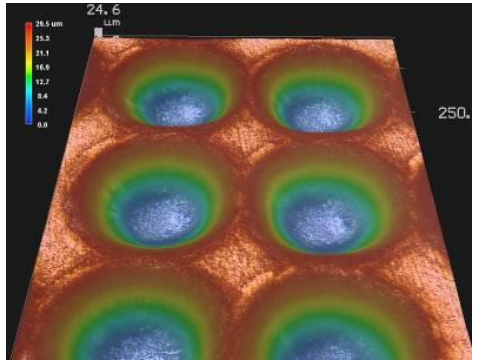
Digital dashboard
Source: wikimedia.org



Light guides in PMMA
Source: ILT

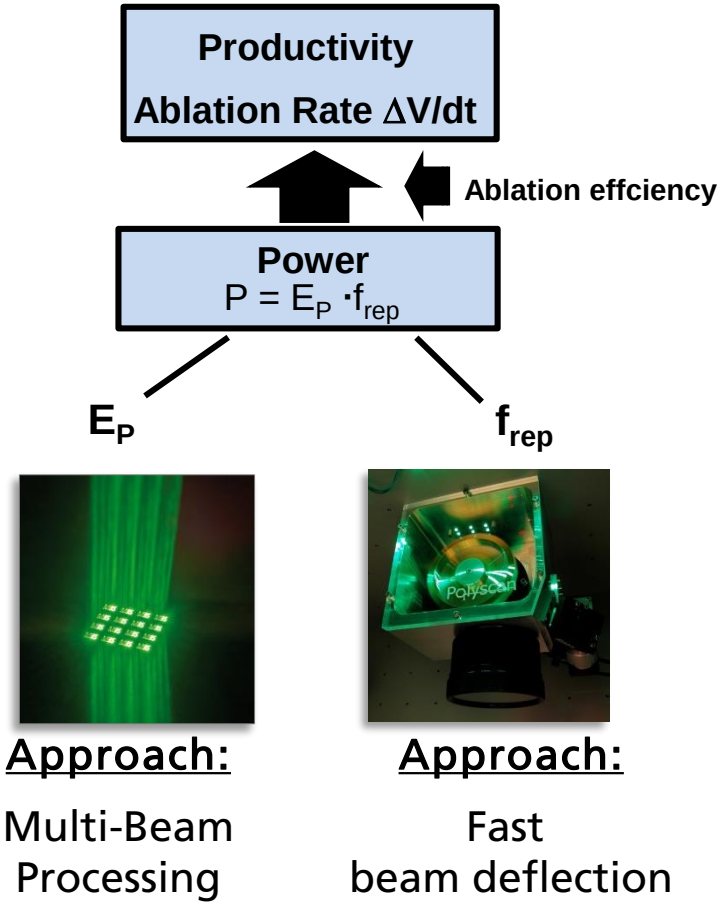


Structured tool surface
Source: ILT



Micro lenses
Source: ILT

Why kilowatt average power?



- Typically ablation rates some mm³/min for ultrafast laser processing
- Quality excellent but productivity much too small for many industrial applications
- Productivity determined by average power

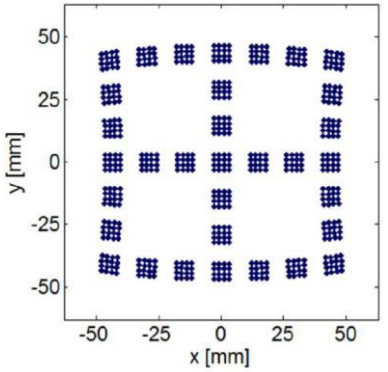
→ Power-scaling to the kW-range

- $P = E_P \cdot f_{rep}$
  - Scaling by pulse energy
  - Scaling by repetition rate

Why individually modulated Multi-Beams? Comparing Scaling Strategies

APPROACH:	FAST BEAM DEFLECTION	MULTI-BEAM-OPTIC
Repetition Rates:	High	Moderate
Pulse Energies:	low	High
Duty Cycle:	Low, dependent on Structure	High
Toolpaths:	Lines, One Direction	Arbitrary
5-Axis-Processing:	No	Restricted
Accuracy	High (with corrections)	Limited by field distortions
Possible structure types	Arbitrary structures	Periodic structures
Scalability	Limited by Oscillator Frequency (combination with multi beam needed for further upscaling)	Limited by optical system

Development of Multi-Beam-Structuring for 1 kW average power and arbitrary, non-periodic structures with high accuracy

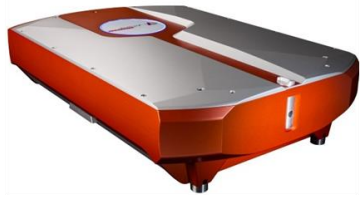


Why individually modulated Multi-Beams?

- Multi-Beam approach unlimited scalability in principle
- Restricted by field distortions
- Only periodic structures

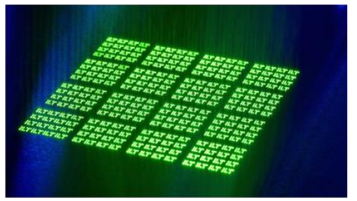
→ Overcoming the restrictions by flexible multi beam approach

Kilowatt USP Laser

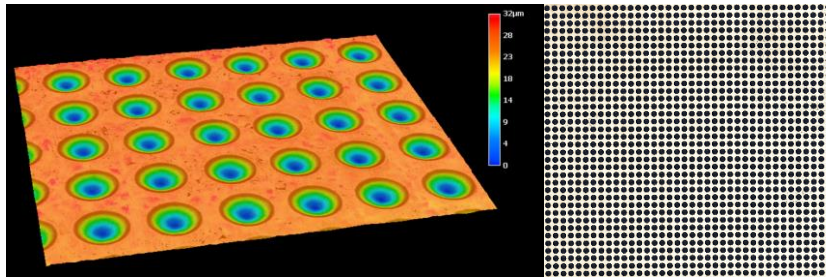


Source: Amplitude

Individually modulated multi-beam array

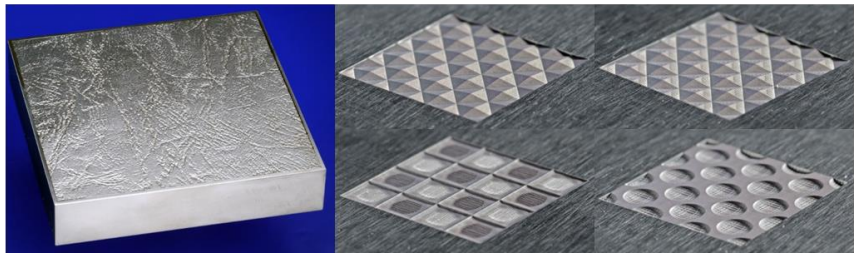


Source: ILT



Source: ILT

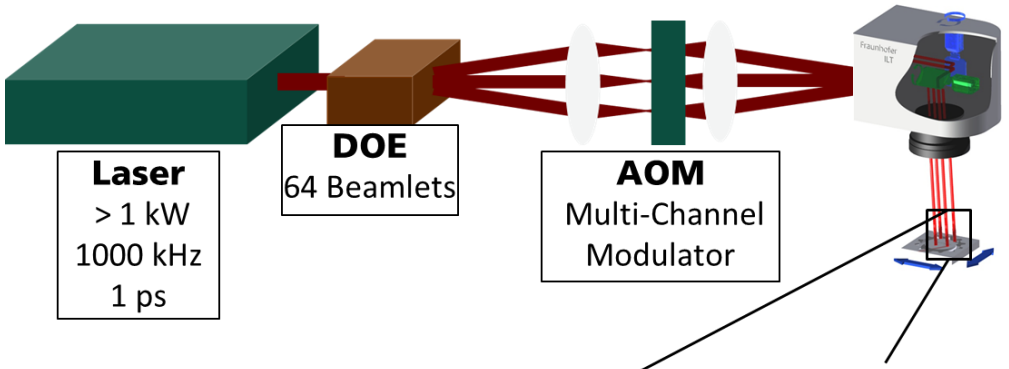
Arbitrary surface Structures with high throughput



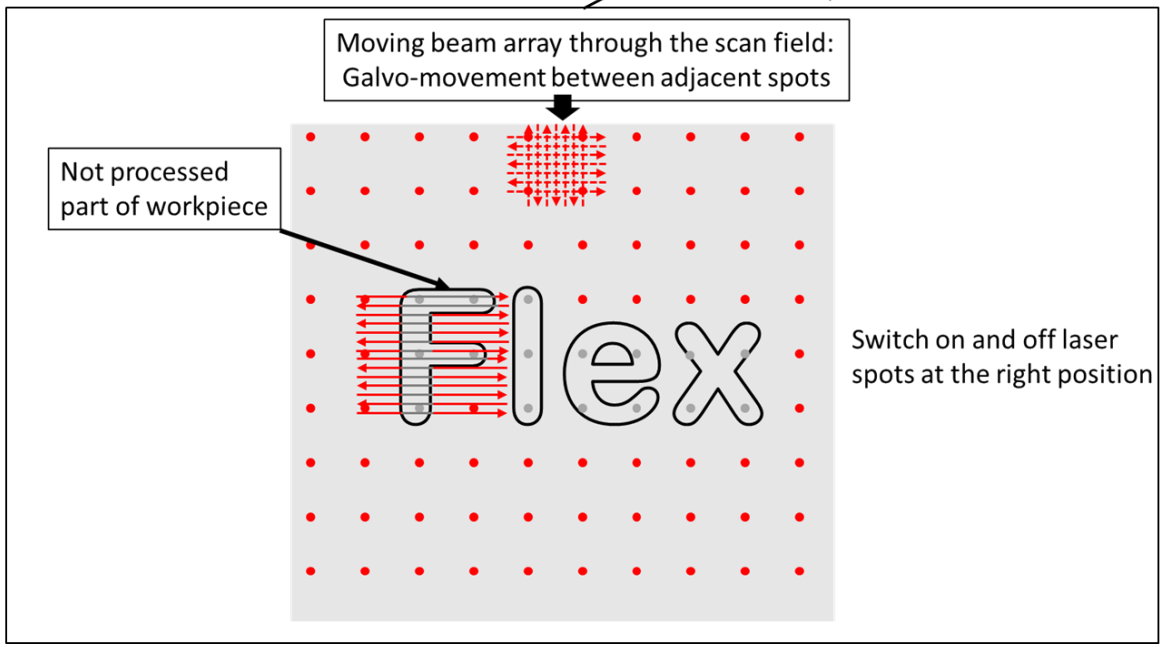
Source: ILT

Concept and Idea: The “Laser Matrix Printer”

- FPGA-based control scheme
- Large spot distance (~5mm) to avoid thermal interactions
- Femtoseconds for high throughput, high quality and high reproducibility
- Pulse Bursts for increased surface quality
- Scan field correction for each beamlet
- Encoder-based control scheme/arbitrary scanning
- Use of pulse on demand/free-trigger



- Approx. 64 Spots
- 1 to 5 J/cm²
- 30 to 50 µm Diameter
- Distance 5 to 10 mm
- Individually switch on and off every single spot during scanning

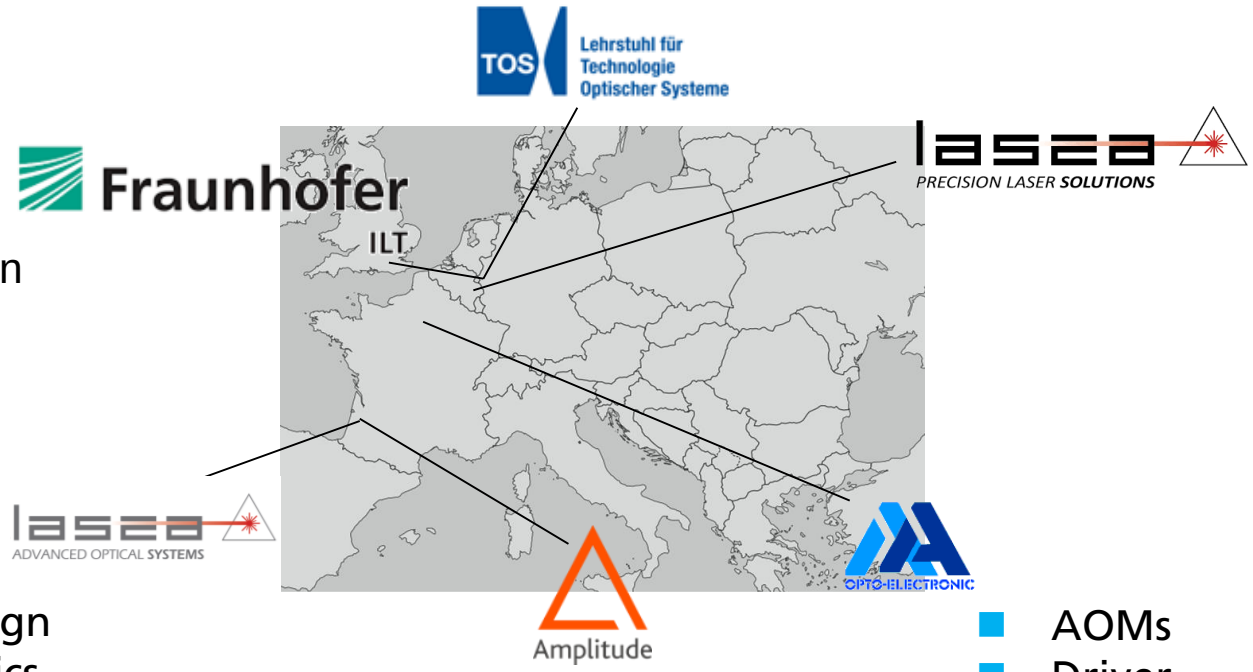


The Consortium

- Optics design
- Thermo-optics

- Coordination
- Control system
- Data acquisition and processing
- Optics prototype
- Application / Validation

- Machine tool
- Control of Galvo and axis
- Integration of components
- Application



- Design
- Optics assembly
- Integration

- High Power USP Laser
- > 1 kW
- < 1 ps
- Burst
- Pulse-on-demand

- AOMs
- Driver

Associated industry partners

Continental

Volkswagen

Procter & Gamble

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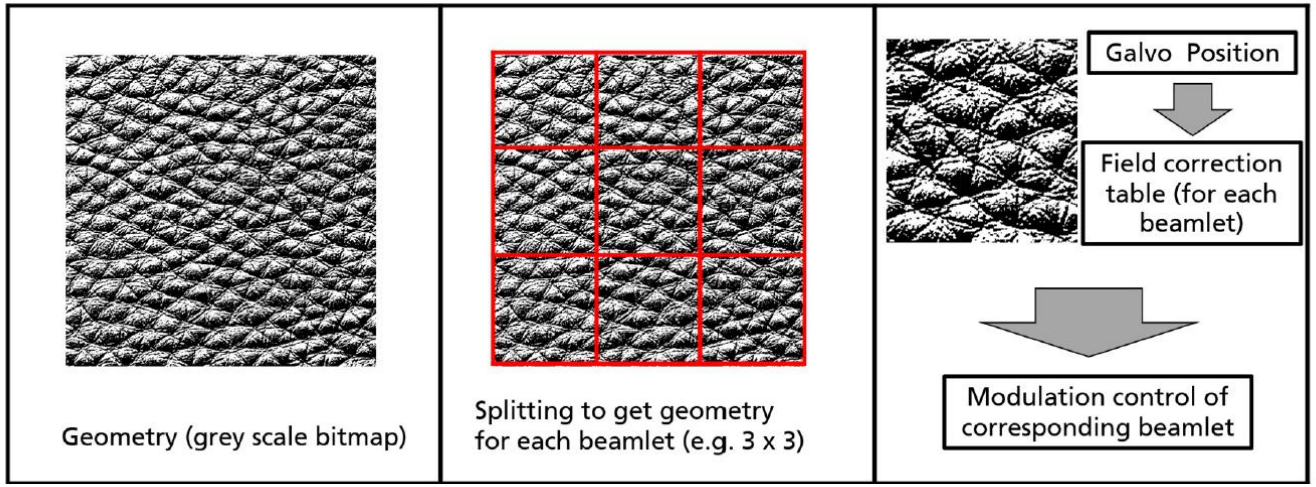
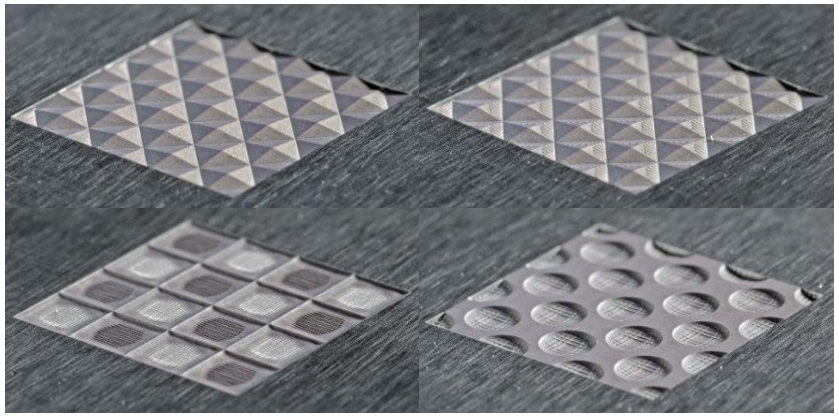
2 MultiFlex in the context of Industry 4.0 and Digitalization

MultiFlex: Data for manufacturing process

- Laserablation → 2.5 D structures
- Bitmap (16 bit) as suitable data format
- Pixelsize determined by pulse distance
- Use-Case:
  - 300 mm x 210 mm
  - Hatch Distance ~ 8 µm

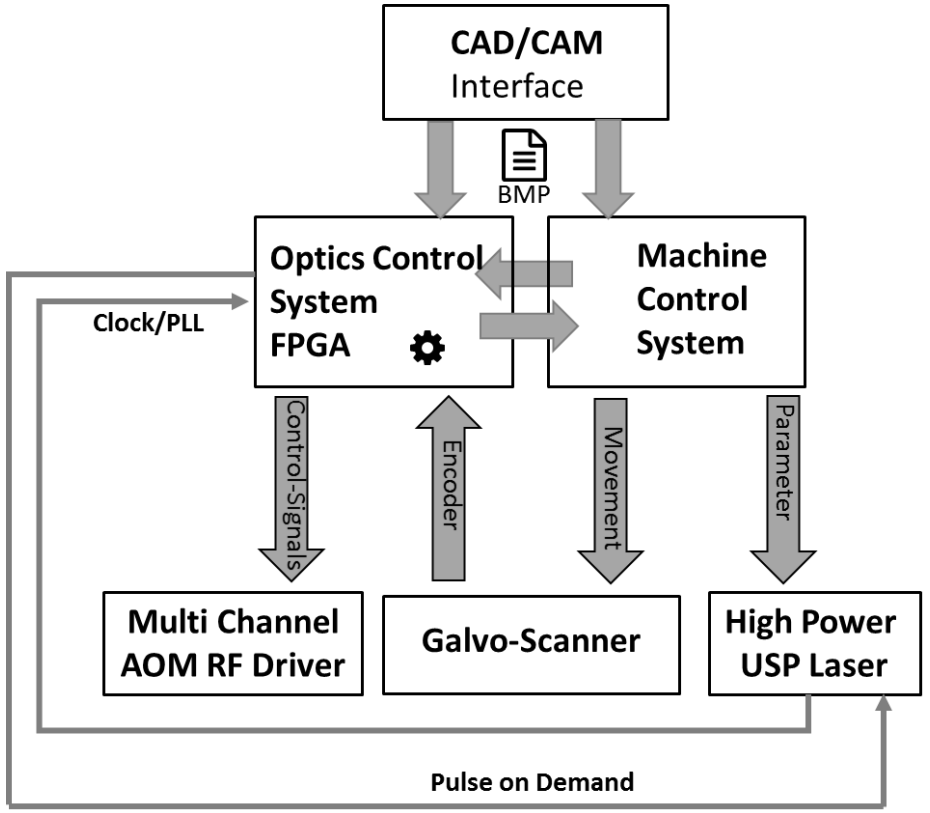
→ 37500 pixel x 31250 pixel (~2.5 GB)

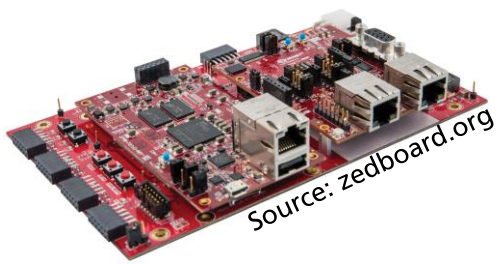


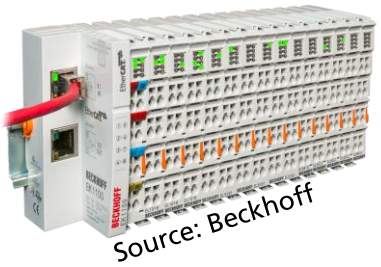


MultiFlex: Control system

- FPGA based control scheme
  - Sniffing and interpolating galvo positions
  - Control of single pulses with laser oscillator frequency (~50 MHz)
  - Control of each 64 modulators
- Pulse on demand
  - Efficient use of laser power
  - Distance based pulse triggering

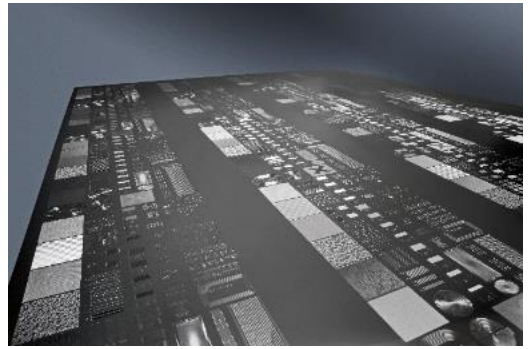






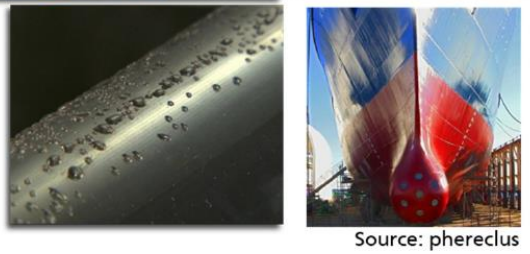
MultiFlex: New process parameters and conditions

- Productivity increase up to x100
- 10 times higher laser power
- 20 times faster control system
- New dimension of flexibility for Multi-beam processing
- New, large area applications possible
- Highest degree of freedom – pixel by pixel ablation
- Efficient use of available laser power
- Replacing environmental problematic technologies



Source: Airbus

Source: Winbro Group



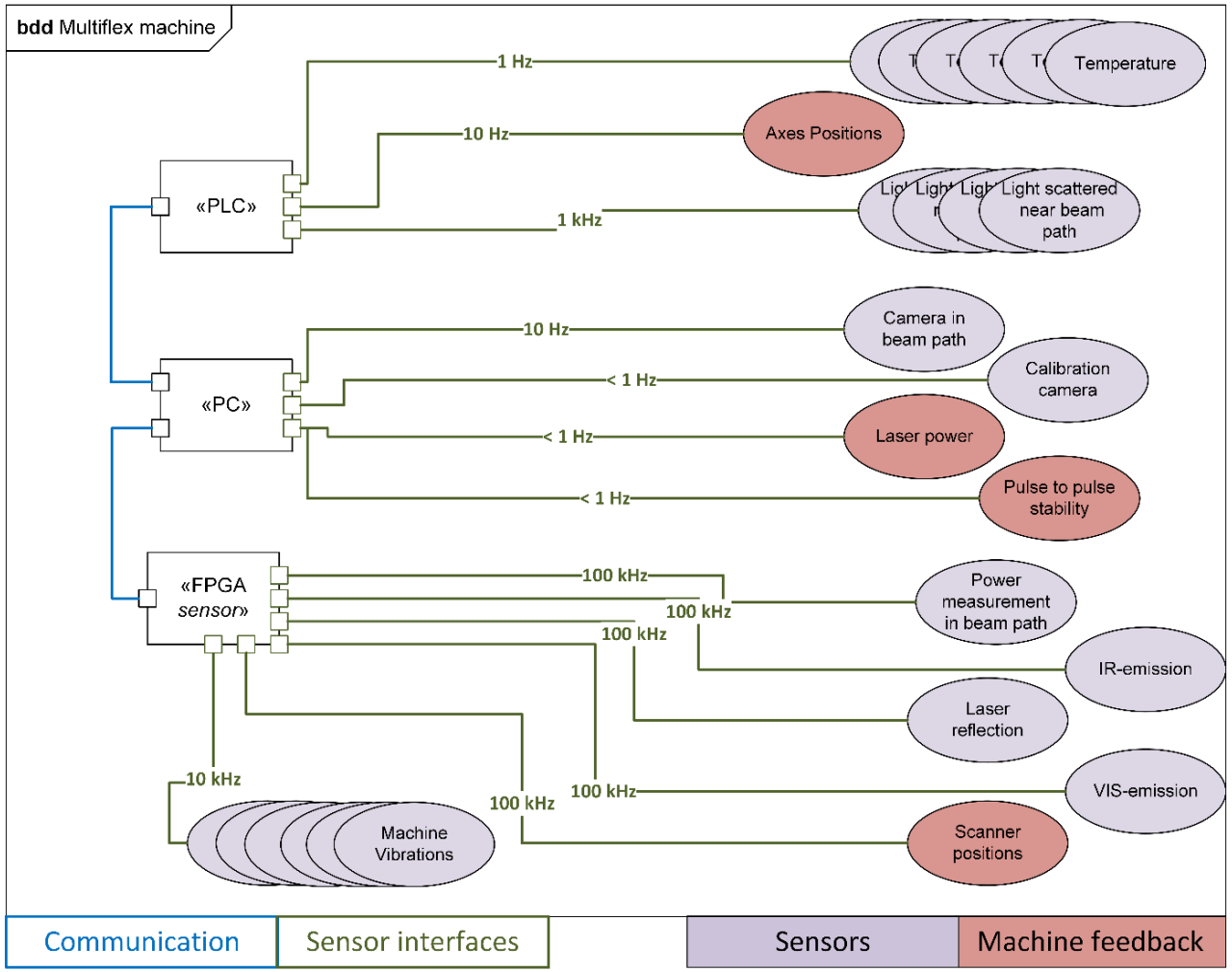
Source: phereclus

Source: ILT

MultiFlex: Process and Machine Monitoring

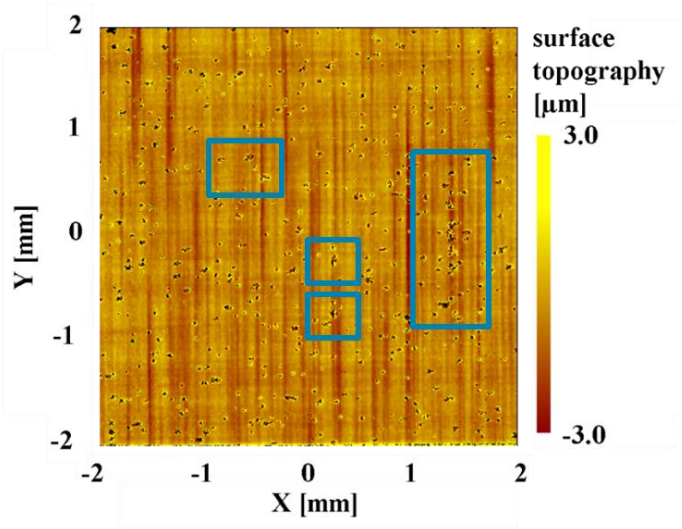
- Monitoring of
  - Machine condition
  - Condition of optical system
  - Process
- PLC/PC
  - Status, “Slow” signals
- FPGA
  - Real time signals
  - Process Monitoring

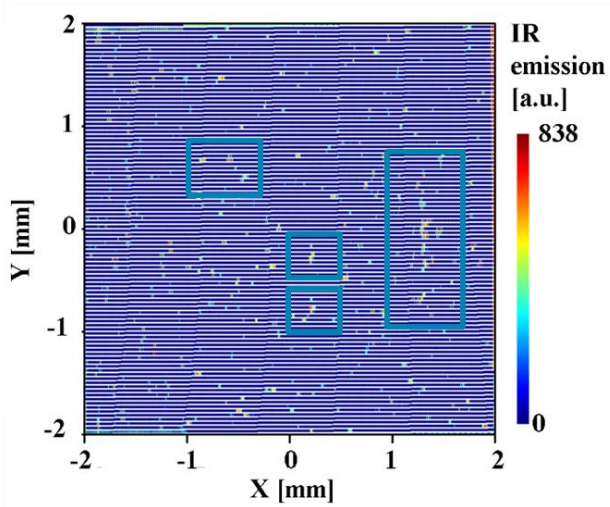
→ ~ 50 Gigabyte per hour

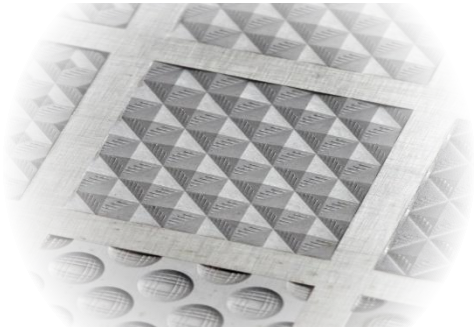


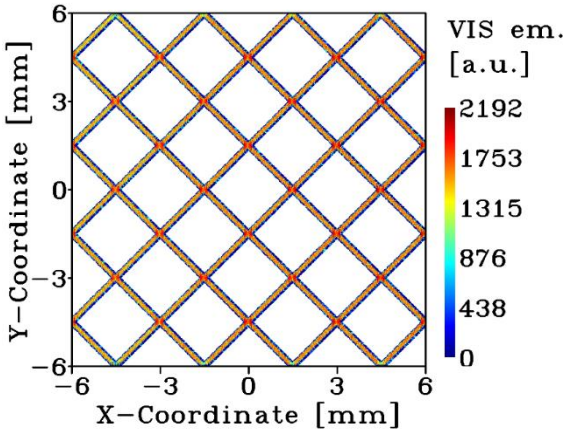
MultiFlex: Use of Artificial Intelligence

- Algorithms for data processing
- Correlation of measured data and processing result
- Analytical for obvious correlations
  - Spot uniformity
  - Laser power
- Mapping of acquired data and galvo positions
- Identifying significant parameters
- Use of Machine Learning algorithms and neural networks for “hidden” and complex correlations









MultiFlex and Digitalization - What would be beneficial?

- Exchange of suitable data processing for laser-based manufacturing with other projects
- Easy to integrate collection of sensors with open software interfaces
- Toolkit for data acquisition and analysis developed for the field of laser-based manufacturing

Where to find us?

- Webpage: www.multiflex-project.eu
- Twitter: @MultiFlex_EU
- LinkedIn: MultiFlex / Group

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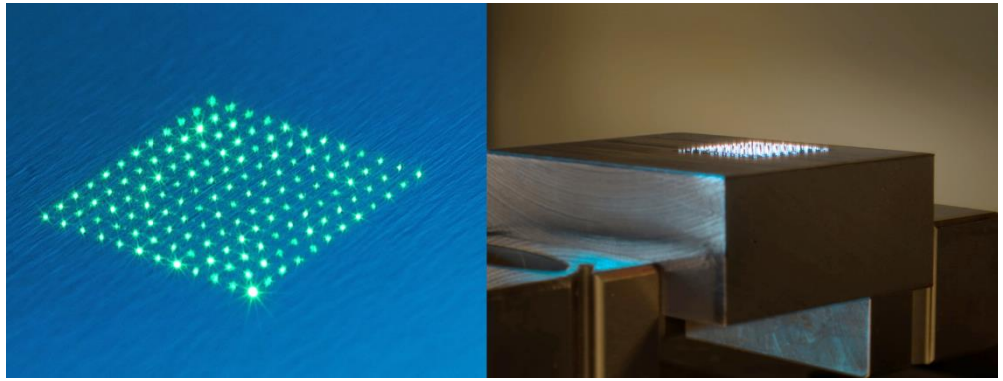

Source: ILT