METAMORPHA newsletter Aug-2026 (#6)

metamorpha

Made-to-measure micromachining with laser beams tailored in amplitude and phase

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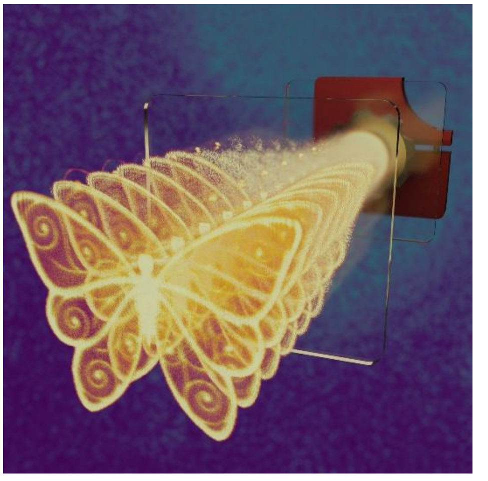
MEMBER OF LIMES
LASER-BASED INNOVATION FOR MANUFACTURING EXCELLENCE AND SUSTAINABILITY CLUSTER



Newsletter #6 has items on the following topics:

- Workshops at METROMEET and AIMEN Laser Week
- Update on the integration of the DataPixel sensor
- FENTISS reports on progress with the TCP/IP integration
- ILT looks ahead to scaling up the optical stamping process
- Philips reports on beam shaping for its use case

More information is available on the project website https://metamorpha.eu

METAMORPHA workshop at METROMEET

Metromeet

METAMORPHA will present some of the project results at the METROMEET 2026 conference (01-02 Oct-2026; Bilbao, Spain). The half-day workshop will be held at the start of the conference (THU 01-Oct-2026; 09:00-11:30 CEST) and will include an overview of the project, a review of the technologies developed and a quantified assessment of the impact on the three project use cases using the METAMORPHA machine (image right).

Full agenda and details will be posted on the conference website: https://metromeet.org/conference-programme-2026

METAMORPHA at AIMEN Laser Week 2026

aimen

METAMORPHA is delighted to be part of the “*Ultrashort Pulse Laser Microfabrication: shaping the future of manufacturing”* event at AIMEN International Laser Week 2026! The all-day event includes presentations, panel discussions and demos, and is held with LIMES projects FABULOUS and OPeraTIC. We hope to see you on **WED 28-Oct-2026; AIMEN Laser Applications Centre (O Porriño, Pontevedra, Spain).**

Agenda and details are available on website: [LIMES workshop at AIMEN Laser Week 2026]()

Consortium

Fraunhofer ILT · LASEA · RWTH Aachen University · fentISS · DATAPIXEL Quality Control Engineering · FORTH Institute of Electronic Structure and Laser · ARDITEC · VIVID Components · Universitat Politècnica de València · CERATIZIT Group · PHILIPS · thyssenkrupp

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Funded by the European Union

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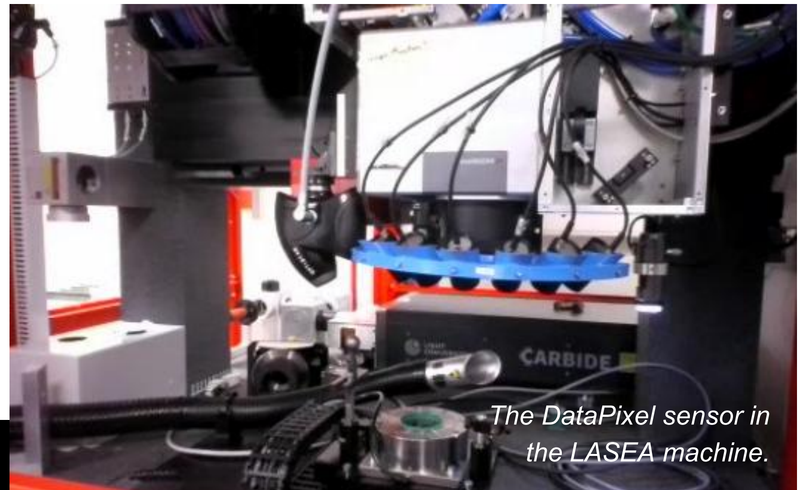
METAMORPHA project milestone!
Integration of DataPixel on-machine optical metrology

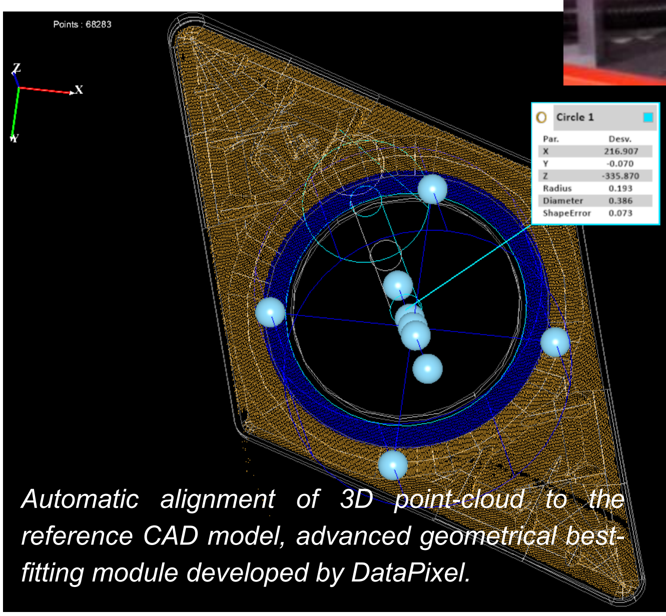
DataPixel is thrilled to announce a major breakthrough in the METAMORPHA project! The team has successfully achieved full integration of the DataPixel optical sensor directly within the LASEA femtosecond laser micromachining platform, paving the way for high-precision, closed-loop manufacturing. This milestone represents a complete end-to-end technical success, encompassing:

Advanced hardware and communication synchronisation

The DataPixel sensor is fully integrated and synchronised via an electronic trigger. Real-time communication with the machine's OMRON controller is seamlessly managed using a robust combination of OPC UA and SSH protocols.



The DataPixel sensor in the LASEA machine.



Automatic alignment of 3D point-cloud to the reference CAD model, advanced geometrical best-fitting module developed by DataPixel.

3D point cloud generation

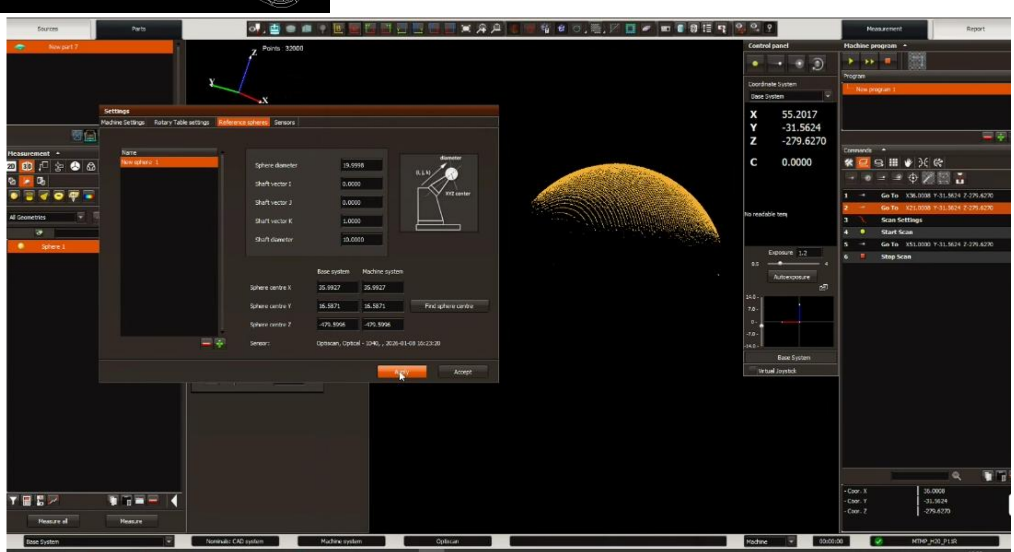
By combining the sensor's optical data with dynamically latched encoder positions, the system can capture highly accurate 3D point clouds on the fly, a task with very demanding synchronisation requirements.

CAD alignment and metrology

The captured point clouds are automatically aligned to nominal CAD models to compute real-time disparity maps, pinpointing deviations instantaneously (see image left).

Automated calibration

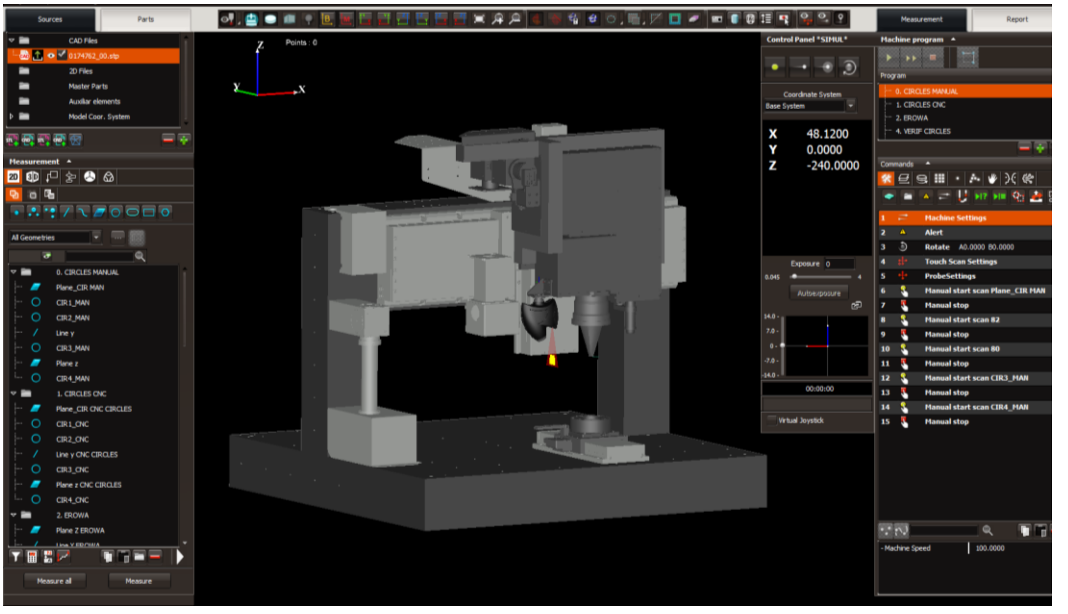
The sensor position and orientation relative to the Cartesian axes of the machine are precisely calibrated by scanning a high-precision reference sphere, as shown in the image (right).



Right: Calibration sphere module.

Funded by the European Union

Right: A digital-twin simulation of the complete METAMORPHA system.



Digital twin simulation

Machine direct/ inverse kinematics simulation, sensor scanning optical simulation and 3D visualisation are the new modules devised in the project for a complete digital twin implementation. They are crucial for sensor integration optimisation, simulation of point cloud acquisition and measurement, system set-up and off-line programming.

Future-proofing via open standards

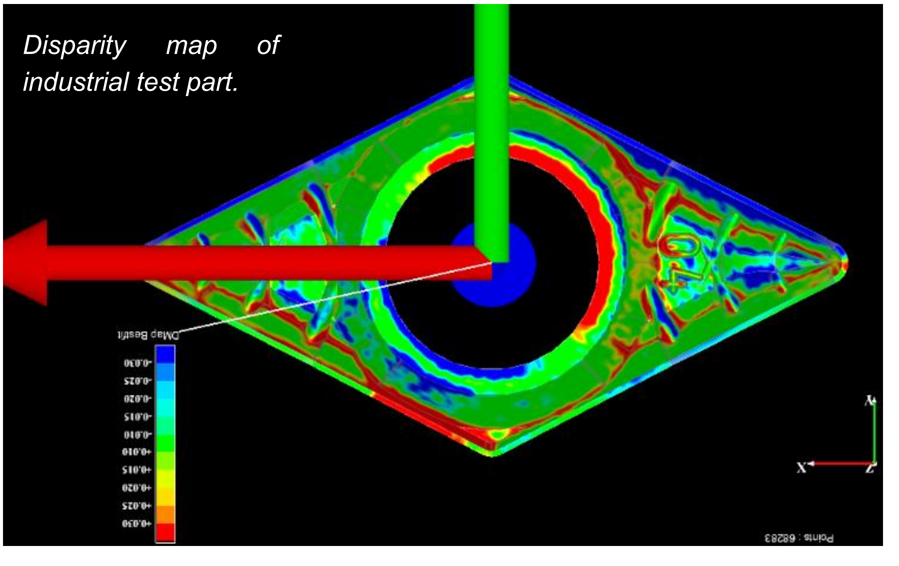
Prioritising open standards such as OPC UA, and the metrology standard ISO 23952 QIF (Quality Information Framework) ensures that this is not just a one-off solution. This architecture ensures high interoperability, enabling seamless porting of this advanced metrology integration to other machine tools and industrial platforms.

Outstanding results with industrial parts

DataPixel is conducting extensive precision testing using industrial components provided by METAMORPHA project partners. The first results are excellent, successfully achieving a remarkable one micron resolution in the axial direction. This level of precision on-machine eliminates part-repositioning errors and significantly reduces cycle times.

What's next?

With the hardware and metrology pipeline verified, the next objective, in cooperation with METAMORPHA partners, is the development of the adaptive slicing module. This software layer will be capable of generating laser processing slices directly from the measured 3D point clouds, bringing the system one step closer to autonomous, self-correcting micromachining.



Disparity map of industrial test part.

Stay tuned for more updates as the team push the boundaries of laser manufacturing precision!

For more info please contact: toni.ventura@datapixel.com

Autonomous boot and TCP/IP integration on Kria KR260

During the recent period of the METAMORPHA project, FENTISS focused on the integration of the LithOS-BM Real-Time Operating System (RTOS) with the data acquisition system (DAQ) FPGA design developed by Fraunhofer ILT, alongside validating TCP/IP communication with the ILT control software (CSW).

A major objective was automating the bare-metal firmware boot sequence on the Kria KR260 board from a power-on reset (cold start). This transition from debugger-dependent to autonomous execution enables the hardware to boot natively from non-volatile memory (micro-SD card) removing the previous requirement for manual firmware download over JTAG (an industry standard).

```
Bus usb@fe200000: Register 2000440 NbrPorts 2
Starting the controller
USB XHCI 1.00
Bus usb@fe300000: Register 2000440 NbrPorts 2
Starting the controller
USB XHCI 1.00
scanning bus usb@fe200000 for devices... 5 USB Device(s) found
scanning bus usb@fe300000 for devices... 4 USB Device(s) found
       scanning usb for storage devices... 1 Storage Device(s) found

Hit any key to stop autoboot:  0
model=SMK-K26-XCL2G
Device 0: Vendor:   Generic  Rev: 1.98 Prod: Ultra HS-COMBO
          Type:     Removable Hard Disk
          Capacity: 60940.0 MB = 59.5 GB (124805120 x 512)
Scanning usb 0:1...
Found U-Boot script /boot.scr.uimg
1549 bytes read in 2 ms (755.9 KiB/s)
## Executing script at 20000000
BOOTP broadcast 1
DHCP client bound to address 192.168.2.99 (2 ms)
7797817 bytes read in 535 ms (13.9 MiB/s)
  design filename = "DAQ_system_bd_wrapper;UserID=0XFFFFFFFF;Version=2022.2"
  part number = "xck26-sfvc784-2LV-c"
  date = "2025/03/18"
  time = "15:59:23"
  bytes in bitstream = 7797692
zynqmp_align_dma_buffer: Align buffer at 000000002000007d to 000000001fffff80
31356 bytes read in 4 ms (7.5 MiB/s)
Using TCM jump trampoline for address 0x40
R5 lockstep mode

[LTE-DBG][429180][CPU0] LithOS-BM 2.1.0-RC0- (none-armv7r-pmsa-bm+zus)
[LTE-DBG][429717][CPU0] Running in lockstep mode
[LTE-DBG][433973][CPU0] partition cold start

METAMORPHA Real-Time Subsystem Application v1.0.0
-------------------------------------------------
[i] Running lwIP v2.1.1
[i] Detected PHY: TI DP83867
[i] Waiting for PHY to complete autonegotiation...
[i] Autonegotiation complete
[i] Link speed: 1000 Mbps
[i] Waiting for IP address from DHCP...
[i] DHCP successful
[i] Interface is UP

[i] Server configuration:
----------------------------
- Board IP : 192.168.2.98
- Netmask  : 255.255.255.0
- Gateway  : 192.168.2.1
- MAC      : 0:a:35:0:1:2
- Port     : 5001

[i] Waiting for connections...
[+] Connection established! (192.168.2.112:51422)
```

The code above shows the boot log of the automated cold start sequence, from U-Boot initialisation to the LithOS-BM lwIP server actively listening for ILT CSW connections.

To achieve this objective, FENTISS developed a custom U-Boot sequence script. Upon power-on, this script handles the entire hardware initialisation automatically by executing the following steps:

1. Triggers the Gigabit Ethernet MAC (GEM) network initialisation to support the lwIP (lightweight IP) stack.

2. Loads the Fraunhofer ILT FPGA bitstream into the PL fabric and applies specific AXI interface configuration, clock settings and resets required by the FPGA design.

3. Loads the LithOS-BM kernel and application binaries into the Cortex-R5F Tightly Coupled Memory (TCM).

4. Releases the Real Time Processing Unit (RPU) to start execution in lockstep mode and halts the Application Processing Unit (APU) to prevent U-Boot from interfering.

With this set-up, FENTISS fully validated the TCP/IP communication between the embedded lwIP server running on LithOS-BM and the ILT CSW client. The data exchange was tested against the communication protocol specification developed by ILT. The embedded server correctly receives requests, parses payload variants and dispatches formatted responses back to the CSW client. (see figures overleaf). This integration establishes the real-time subsystem as an asynchronous bridge between the Windows-based desktop application and the underlying FPGA DAQ logic.

It enables the configuration of process parameters, and the retrieval and delivery of surface roughness values and sensor measurements to the user interface by translating high-level client commands into low-level, bare-metal C functions.

For more info please contact
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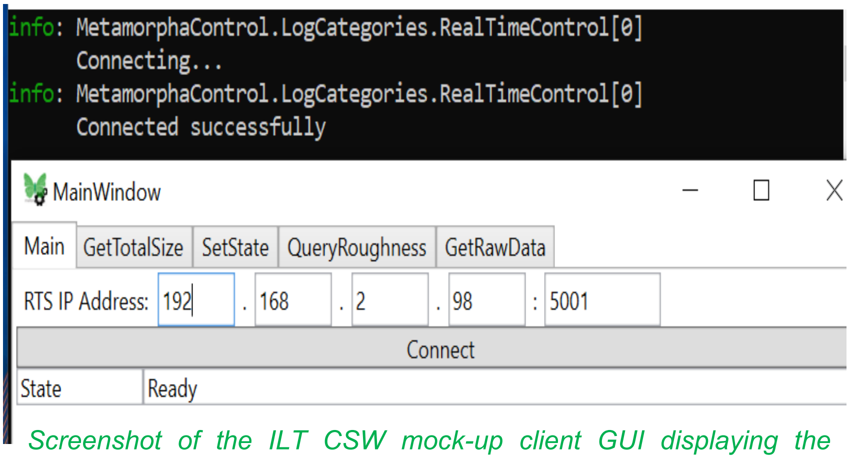
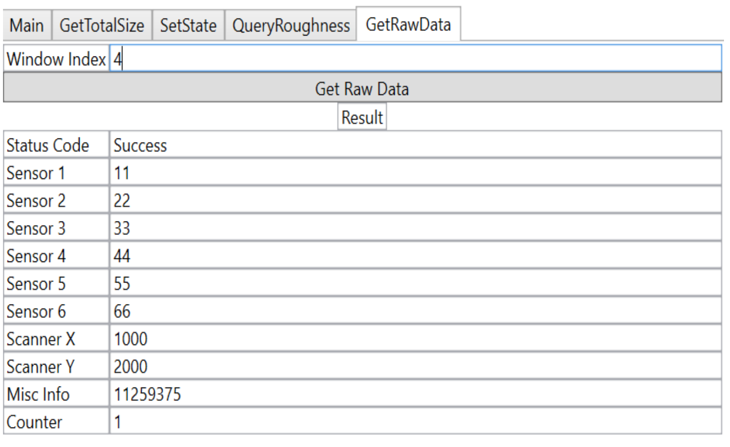


Screenshot of the ILT CSW mock-up client GUI displaying the successful connection.



Screenshot of the ILT CSW mock-up client GUI displaying received data with "success" status code.

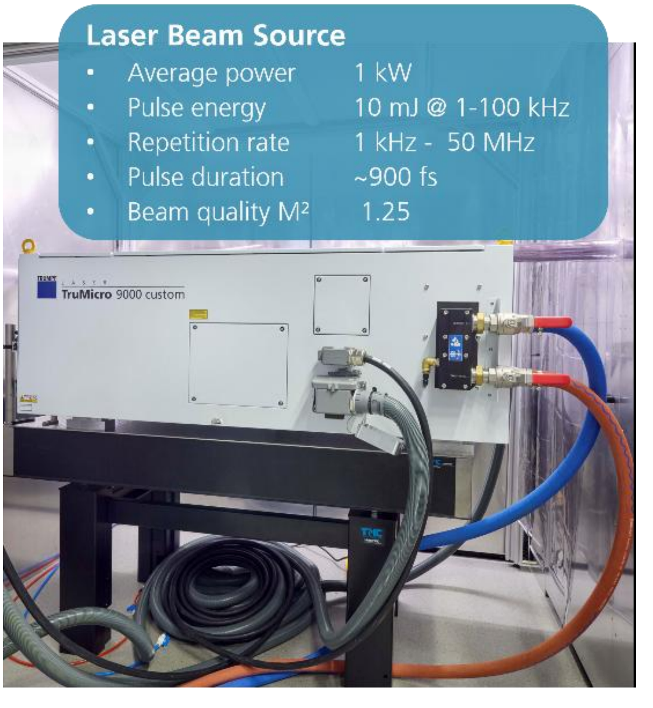
Next steps

Now that the TCP/IP communication is fully functional, the focus will shift from the current mock data testing environment to end-to-end hardware execution. The next objective is to couple incoming client requests with actual hardware operations. This involves coordinating directly with the FPGA DAQ to capture synchronised sensor data, feeding that data into the UPV machine learning model hosted by LithOS-BM, and ultimately delivering surface roughness predictions to the ILT CSW.

Scaling up optical stamping with higher pulse energies

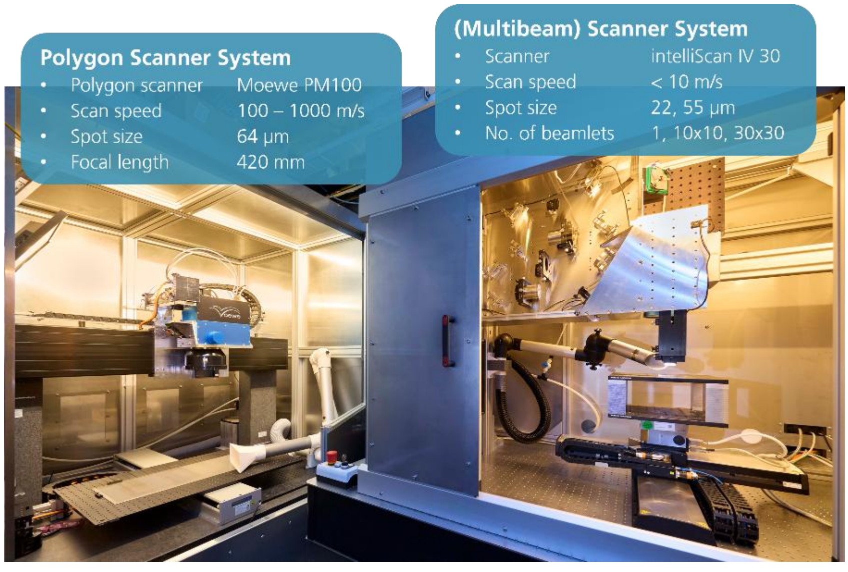
Fraunhofer ILT

Optical beam shaping activities at Fraunhofer ILT have recently taken an important step forward with the relocation of the double-SLM set-up to a new high-energy laser source. The system is now operated with an Amphos 8000, providing pulse energies of up to 2 mJ. This represents a significant improvement compared with the previous configuration, where only 800 µJ were available. The higher pulse energy directly expands the accessible parameter range and enables the generation of larger and more complex beam shapes.



Previously, the size of the achievable intensity distributions was limited by the available energy per pulse. With the new source, these limitations are substantially reduced, opening up new opportunities for process development and scaling.

In parallel, major progress has been achieved in the field of large-scale optical stamping. Using a diffractive optical element (DOE) in combination with a 1 kW laser system, the TruMicro 9000, pulse energies of 4.6 mJ were successfully converted into an optical stamping field of 1×1 mm^2. This approach allows an entire structured area to be processed with a single laser pulse, instead of scanning the pattern point by point. As a result, the process time was reduced by ~96 % compared with a conventional scanned process. This demonstrates the strong potential of optical stamping as a highly productive approach for laser-based surface structuring, especially for large areas or repetitive microstructures.



The results show that beam shaping and optical stamping can significantly increase throughput while maintaining a high degree of flexibility in the generated intensity patterns. By combining high pulse energies with tailored optical designs, it becomes possible to transfer complex structures efficiently and with high precision. This is particularly relevant for industrial applications where both productivity and process stability are key requirements.

However, several challenges remain on the path toward even higher productivity. One of the main limitations when using very high average powers is thermal drift within the optical set-up, which leads to a shift of the focal position. At present, this effect limits the optical stamping process to repetition rates of ~10 kHz. Active work is currently ongoing to improve understanding, compensate and ultimately reduce this focus drift. The goal is to enable the use of significantly higher repetition rates in the future.

5 MHz	frequency	100 kHz
3 µJ	Pulse energy	~3 mJ
15 W	Power	300 W
17 m/s	Scan speed	-
100	Number of repeats/pulses	1000
~20 ms	Time per repeat	10 µs
2 s	**Process time**	**10 ms**

Table showing the current (left) and planned (right) processing parameters for the METAMORPHA optical stamping process. A processing time improvement of two orders of magnitude is realistic.

If successful, this next development step could increase the productivity of optical stamping by another factor of ten. Combined with the already demonstrated process time reduction, this would correspond to an overall productivity increase of up to a factor of 100 compared with conventional scanning approaches. This makes optical stamping a highly promising technology for future high-throughput laser processing applications.

For more info please contact Sönke Vogel
soenke.vogel@ilt.fraunhofer.de

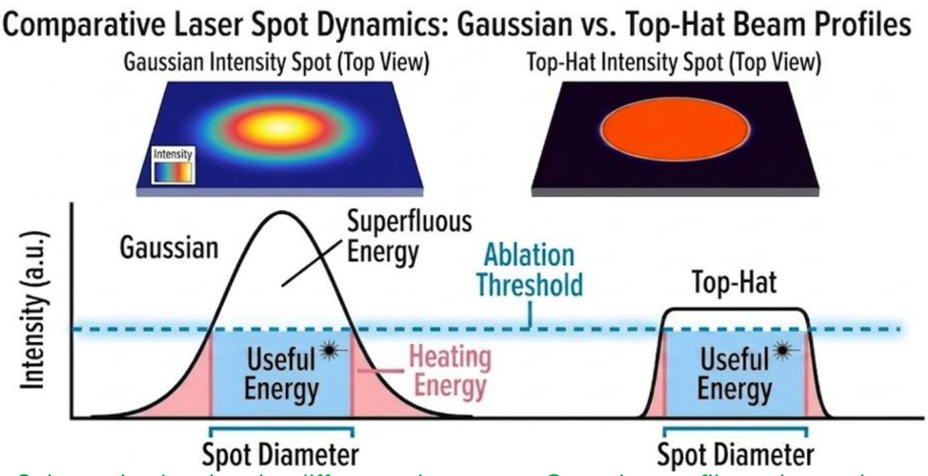
Beam shaping for the Philips use case

As has previously been communicated, Arditec has demonstrated reduced waste (close to 100 %) energy consumption (up to 60 %) and carbon footprint (25 %) compared with traditional manufacturing processes for the Philips use case by adopting the METAMORPHA platform. To realise these potential sustainability gains, Philips has focused on the details of how the process can be implemented on the METAMORPHA hardware in a way that fully leverages the unique aspects of the platform.

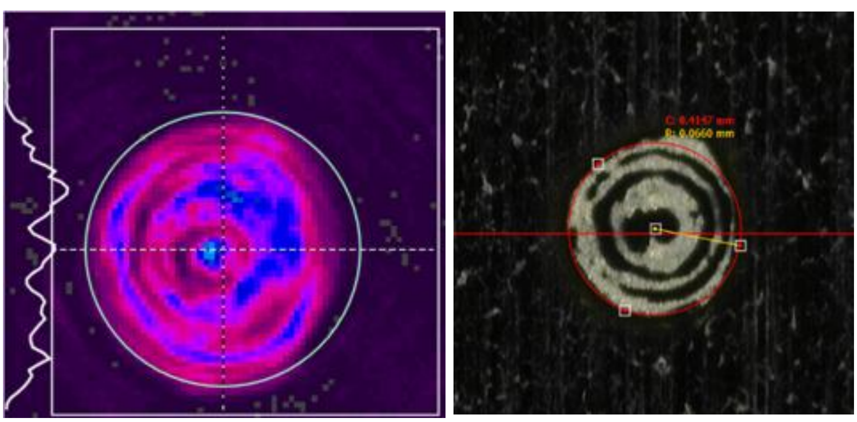
It has already been possible to explore some unique complex beam shapes that the dual spatial light modulator (SLM) configuration allows while the full functionality of the METAMORPHA machine with all its sensors and closed loop control is being integrated.

Experimental approach

With the other project partners, Philips is testing a new way to shape laser light that could make precision laser processing faster, cleaner and more flexible. Normally, laser cutting and ablation uses a Gaussian beam; *i.e.* bright in the middle and dimmer at the edges. This means the centre gets more energy than needed while the edges do not get enough, which wastes power and limits quality. By reshaping the beam into a “top-hat” profile (*i.e.* uniform power across the beam profile), energy is delivered more evenly, improving cut quality and using the laser more efficiently.



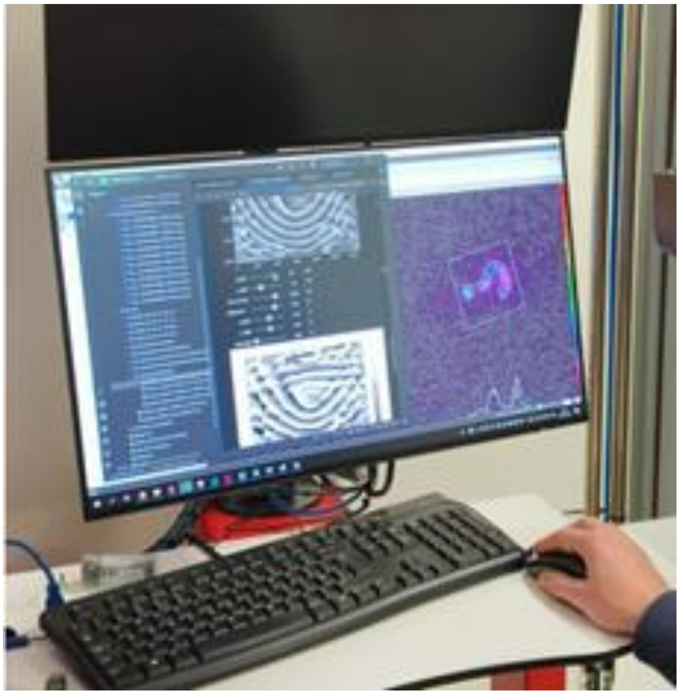
Schematic showing the difference between a Gaussian profile and a top hat.
[Adapted from “[Why Use a Flat Top Laser Beam?](#)” Edmund Optics Inc.]



Images showing the beam profile for a top hat (left) and the resulting ablation profile for a single pulse (right). The machine is currently being tuned to increase the uniformity of the profile.

METAMORPHA goes one better: the system uses two programmable SLMs. One shapes the beam across the surface, and the second controls how the beam behaves as it goes deeper into the material. Together they keep the energy consistent through the workpiece, giving engineers more freedom to design complex parts and potentially increasing processing speed while reducing waste.

This work is a collaboration with RWTH (phase-mask design), ILT and LASEA (implementation on the METAMORPHA platform). Simulations already look promising, and lab experiments are underway to confirm real-world gains.



Experimentally setting up the phase masks

Theoretical approach

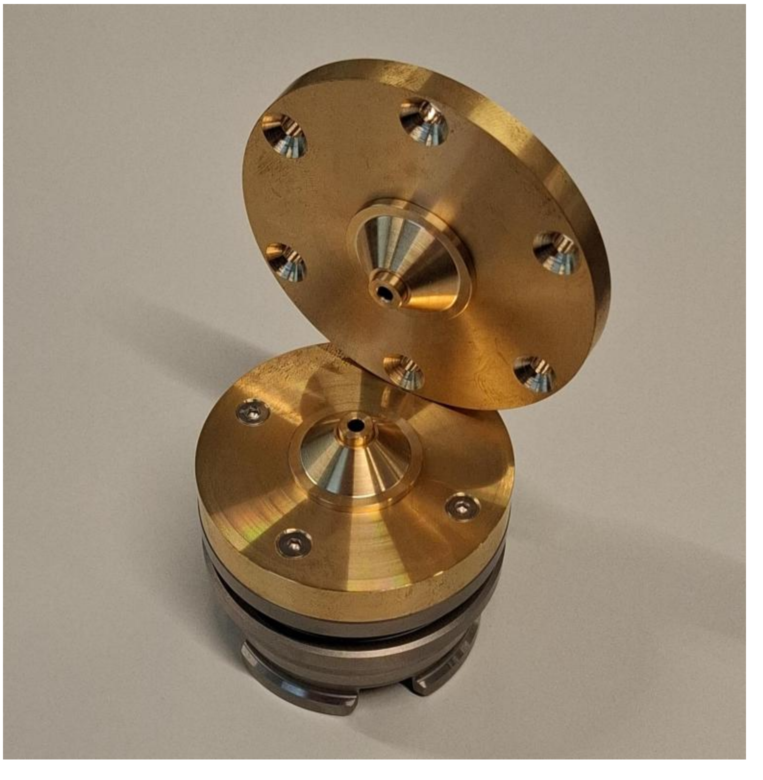
Parallel to the experimental approach, Philips has worked with FORTH to explore how to simulate the effect of different beam shapes on material interaction. As there are few limits to the beam shape designs achievable with the METAMORPHA system, Philips and FORTH are building a theoretical understanding of the specifically tailored beam shapes that the team wish to generate using the SLM phase masks and subsequently explore experimentally. Aside from studying ablation efficiency for different beam shapes, the aim is also to explore process robustness by quantifying the loss in efficiency when the beam shape deviates from its ideal state.

Enhanced process control

Besides exploring advanced beam shaping, Philips is setting up experiments with sensors to enhance process feedback and control. A secondary-emission sensor, which measures reflected light and emissions from the workpiece, will be used for real-time monitoring and closed-loop process control. The team is currently applying the final touches to the sensor installation; once complete, it will begin gathering data and testing how best to use these signals to improve quality, efficiency and reliability.

Next actions

To enable extensive process optimisation with the LASEA METAMORPHA platform, Philips has produced a large batch of special use case samples and a custom sample carrier. These are now staged for the next round of experiments; the next step is to run many tests to evaluate different sensor configurations, beam shapes and closed-loop control strategies with the goal of finding the best combinations for quality, speed and efficiency.



Designed carrier for the use case products. uses a universal EROWA^{TM} mounting system and includes a beam dump which is needed for the coming experiments.

For more info please contact winand.slingenbergh@philips.com