METAMORPHA newsletter Feb-2024 (#3)

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

Welcome to the Feb-2024 METAMORPHA project newsletter!

This newsletter has items on the following topics:

- First of three end user focus articles on Philips
- Adaptable laser machine being developed at LASEA
- Sustainability assessment work carried out by ARDITEC
- The software interface for the METAMORPHA machine being developed at ILT
- Automatic machining code generation using AI (UPV, ILT + Philips).

Please join the METAMORPHA LinkedIn group to keep up with project developments!
https://www.linkedin.com/company/metamorpha

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

METAMORPHA end user focus: Philips

Since the company was founded in 1891 by Gerard and Anton Philips, it has been a pioneer in the manufacturing of consumer and medical products. Today Philips sees the potential of laser-based manufacturing, driven by the rapid power scaling of industrial ultra-short pulse (USP) laser sources and systems, for the precision metal components it requires for its shaving products. However, the METAMORPHA system that applies this newly available technology has many difficulties that need to be solved before it can meet Philips high manufacturing standards.

Worldwide customers rely on the quality of Philips products. Our ambition is to improve the lives of 2.5 billion people by 2030. Since 1950, manufacturing of personal care products has been carried out at the Philips factory in Drachten located in the north of The Netherlands.

Consortium

Fraunhofer ILT, LASEA, RWTH Aachen University, fentISS, Datapixel, FORTH, ARDITEC, Vivid Components, Universitat Politècnica de València, Ceratizit Group, Philips, thyssenkrupp

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The METAMORPHA approach has relevance to many other applications that currently rely on robust and proven technologies. Although these manufacturing technologies are often very mature, the current standards also limit the product solution space. Here METAMORPHA will bring new solutions to the market. Working with the wide range of disciplines covered by the METAMORPHA consortium helps Philips to generate a deeper understanding of complex physical and digital scenarios.

Through learning about this complexity, Philips can support the team with its experience and define requirements at a very early stage of technology development. The public and collaborative character of Horizon Europe enables Philips engage with the required resource and involvement and to push technology readiness levels (TRLs) beyond industry norms.

As part of the long-term vision for a more sustainable company Anton and Gerard would certainly have supported METAMORPHA and its aims!

Gerard (left) and Anton (right) Philips founded the company in 1891.

For more info, please contact:
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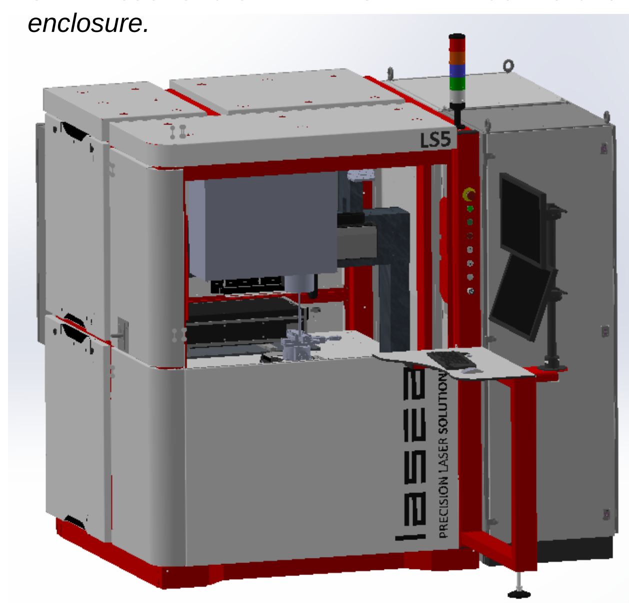
METAMORPHA laser machine development

LASEA as a laser machine manufacturer participates in the METAMORPHA project to design, develop and validate a laser machine which is both flexible and plug-and-play compatible with the three project use cases (Philips, Ceratizit and tkSE). This is extremely challenging since the needs of each application are very different. The Philips application requires several different laser processes, the Ceratizit workpiece is a 2.5D shape which has smooth surfaces and a closed-loop system and finally the tkSE process involves a large roller processed with a specific beam profile. Using current technology, these three different applications would require several laser machines, with different axes and beam characteristics. In the METAMORPHA project, LASEA will design and produce a single laser machine which can easily change configuration to accommodate each of the three applications. Moreover, the integration of the optical module and control unit (from ILT), the monitoring system (from Datapixel), the machine learning (developed by UPV) and the real-time subsystem unit (from FentISS) will increase the productivity and versatility of the laser machine.

LASEA will develop the machine throughout the project to demonstrate its agility, reconfigurability and compatibility with a range of commercial laser sources.

CAD model of the METAMORPHA machine and enclosure.



During the first period of the project, LASEA has worked with the project partners to determine the different interfaces (optical, mechanical, electrical and software) of the modules to be integrated into the laser machine, as well as the detailed specifications for the three use cases. Based on this information, LASEA has started the design based on a standard LASEA machine enclosure to guarantee operator safety. The machine will have all the features of a Class I commercial laser machine, to be as close to market as possible by the end of the project.

For more info, please contact Anne Henrottin ahenrottin@lasea.com

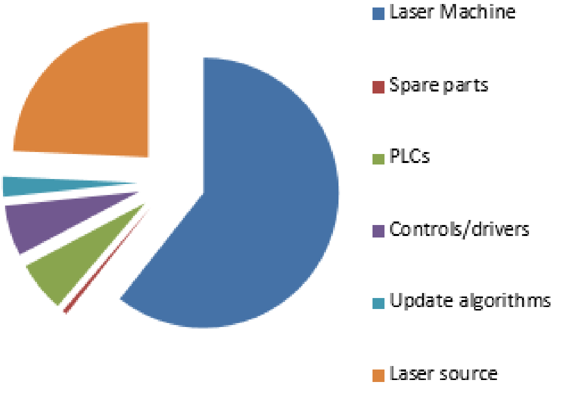
Sustainability impact assessment

As lead of the sustainability studies within METAMORPHA, ARDITEC is undertaking the techno-economic assessment and environmental evaluation of the three baseline scenarios (Philips, Ceratizit and tkSE). The objective is to establish a basis that will be used to calculate the benefits (environmental, economic and social) of METAMORPHA.

ARDITEC will work with primary data collected directly from the relevant partners (with any gaps filled using existing literature or the Ecoinvent database). Several meetings have been held with the end-users to build the inventories for the models. In general, the quality of the data is high since every process is performed at industrial scale.

Techno-economic assessment (TEA)

This task evaluates the economic drivers that the METAMORPHA laser and optical systems should focus on to reach competitiveness. The maturity of the laser system itself is behind that of the technologies used by the partners. Hence, this task considered a sensitivity study of the different economic aspects of the laser process to set development thresholds and key focus areas on the economics, as well as the potential business model. Different economic indicators such as CAPEX/OPEX distribution were considered (see right). The TEA will be submitted in Feb-2024.

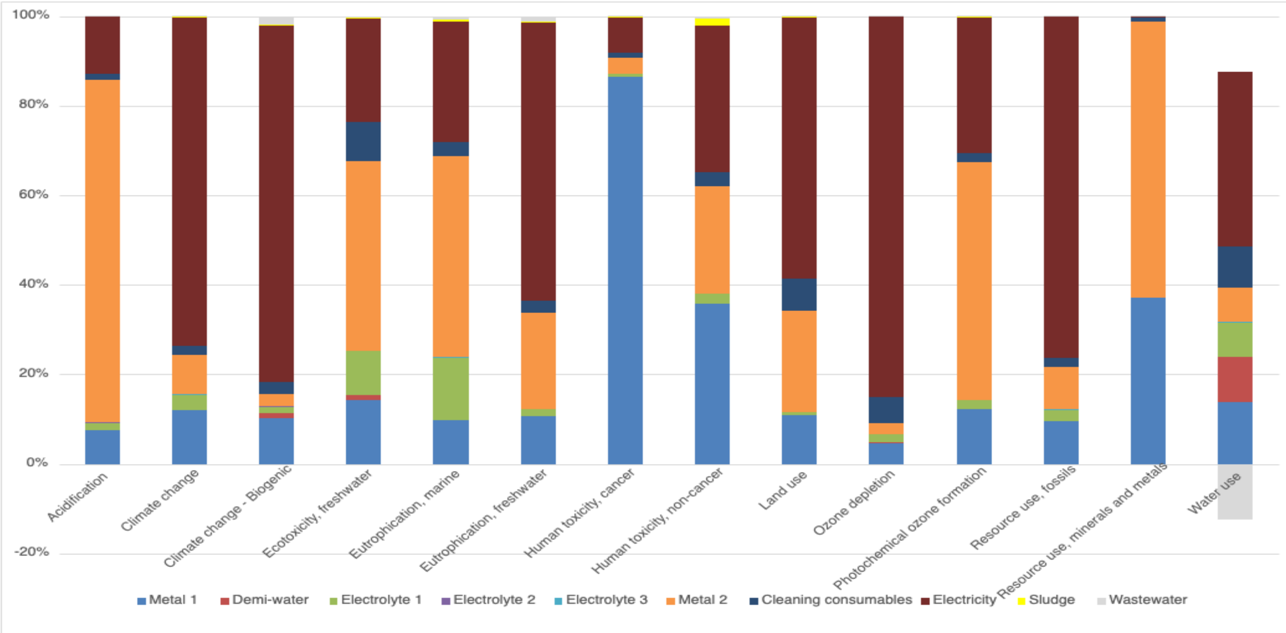


CAPEX cost distribution of the METAMORPHA machine.

Life cycle assessment and environmental evaluation

Concerning the Life Cycle Assessment (LCA) of the METAMORPHA technology, ARDITEC is finalising the first step, which consists in evaluating the baseline scenario that will be compared with the results obtained later in the project. The Association has been organising recurring meetings with the three end-users to elaborate data inventories including energy, water, material resources, emissions and waste. This preliminary work allowed the calculation of the impact distribution of each process currently used by the partners and to identify the hotspots such as specific chemical use or energy consumption. The graph on the following page shows the results for one of the baseline scenarios which includes the distribution of the different inputs/outputs according to the impact category considered (global warming potential, acidification potential, fossil resource use, water depletion *etc.*). [For confidentiality reasons, some of the flows are not detailed.]

Impact distribution for one of the baseline scenarios assessed in METAMORPHA.



The remaining tasks, especially the economic evaluation (life cycle cost or LCC) and the social LCA (SLCA) will be conducted in parallel with the environmental study. They share the same goals and scope, system definition, functional unit and assumptions. The data collection is ongoing for both studies and the results will be available by Jun-2024.

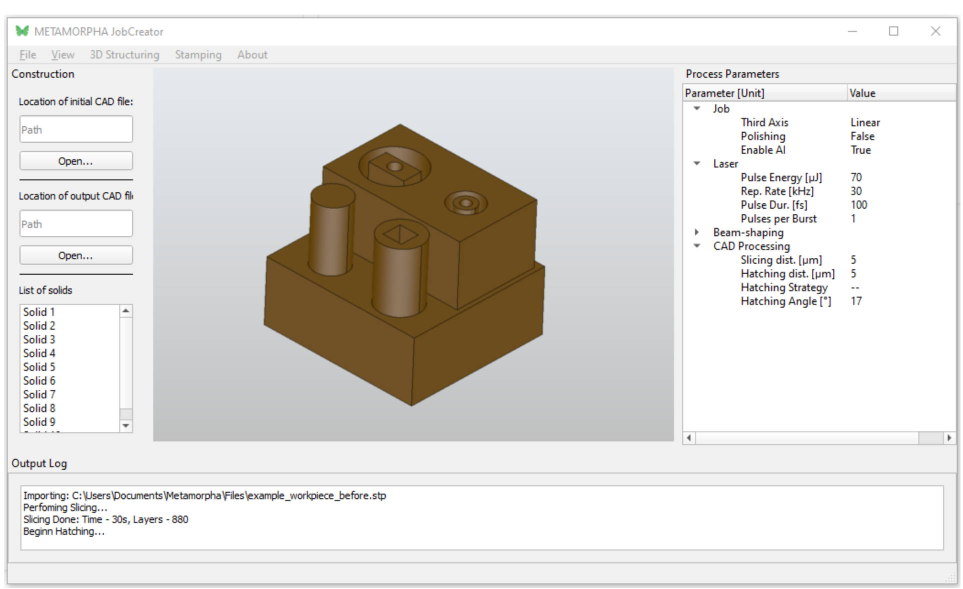
All stakeholders are invited to visit the website for more details on the sustainability studies and to follow the LinkedIn group!

For more info, please contact Leo Staccioli: leo.staccioli@arditec.net

User-facing software development

Fraunhofer ILT

In METAMORPHA the main user-facing software (*JobCreator*) is split into two parts. This enables the encapsulation of certain features while allowing a machine operator with limited knowledge of laser processing and computer-assisted design (CAD) to run the laser machine, directly saving employee costs. The part and process design can be off-loaded to



A screenshot of the draft METAMORPHA JobCreator GUI. In the centre is a 3D-viewer to visualise the work, in this case an example workpiece. On the left, the CAD models can be imported and managed. On the right is a list of the process parameters for the currently selected part.

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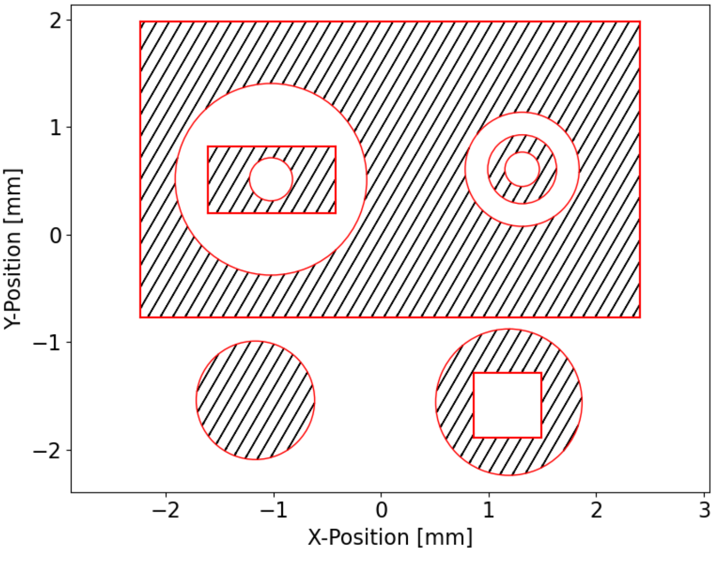
dedicated designers who have in-depth knowledge. Additionally, the use of machine learning, especially predictive models will assist these designers in their work (see pg. 6).

This article focuses on the design software called *METAMORPHA JobCreator* which will ultimately provide these capabilities. The figure on the previous page shows a draft version of the *JobCreator* graphical user interface (GUI). Note the central 3D-viewer to inspect CAD models and the list of parameter settings on the right.

The expected workflow will have the designer import CAD models of both the initial workpiece as well as the desired result after processing. The *JobCreator* software will then subtract these models to obtain the parts which need to be removed. Since laser ablation is also a subtractive method, this harmonises nicely with the capabilities of the METAMORPHA machine. [In the figure such a step has not yet been performed so the whole example workpiece is shown.]

Each disjoined part for removal can be selected by the designer and given individual process parameters which best reflect the requirements at the part location. This is where machine learning can be used to assist the designer and make suggestions based on fixed initial properties, for example the material or the required surface roughness.

Laser ablation is a 2.5-dimensional process, meaning material is removed layer by layer and depth is achieved by adding more layers. Each part to be removed is therefore divided into such layers by a program called a slicer. For the example workpiece shown in the GUI screenshot, such a slice is shown below. The laser is scanned across these layers based on a selected strategy. The simplest strategy is just to move the laser back and forth across the workpiece with a given speed. This is represented by the black lines called hatches. Another strategy would be to move along the contours of the slice (red lines) while incrementally contracting them.



One layer of the example workpiece from the GUI screenshot. The slicer program has calculated the contours of the workpiece (red lines) as well as hatches (black lines) which represent the movement during laser processing.

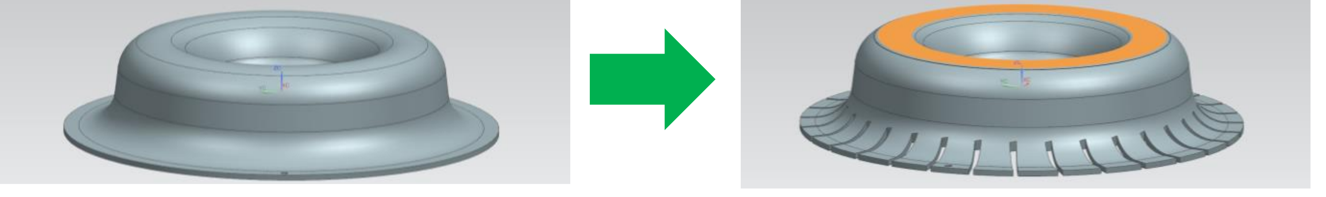
Because of the flexibility inherent to the METAMORPHA laser machine, it is possible to adjust the process parameters and even the laser beam for each individual hatch. However, a balance must be struck between allowing this high degree of freedom and a reasonable amount of work required to create a machining job. This is again a task suited for machine learning, which can complete any blank parameters based on initial conditions, requirements and previous user input, similar to the auto-correct and text prediction in a smartphone. (See next item on pg 6!)

For more info, please contact Moritz Battermann: moritz.battermann@ilt.fraunhofer.de

AI-generated machining code

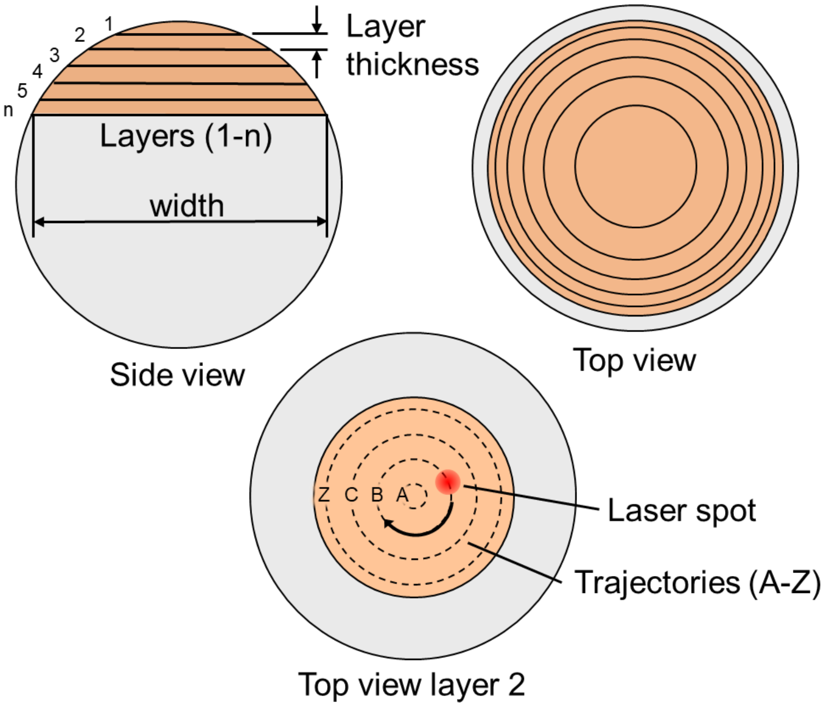
Fraunhofer ILT · UNIVERSITAT POLITÈCNICA DE VALÈNCIA · PHILIPS

Productivity is key to a competitive cost price when using expensive manufacturing equipment. Ideally the laser in the METAMORPHA machine should be machining continuously. To ensure that the laser is on as much as possible, other routines on the machine should be done in parallel or should take as little time as possible when done sequentially. One of the routines on the machine that is likely to consume a significant amount of time is the calculation of the machining trajectory. Taking the Philips use case as an example, every product will need its own dedicated machining code based on a measurement in advance, as shown below.

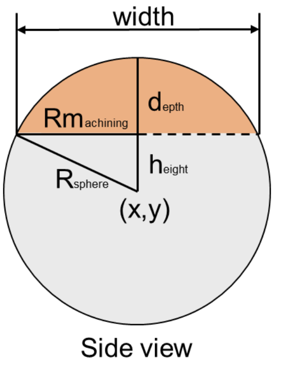


The METAMORPHA machine will process the input blanks (left) into intricate parts for shaving products (right).

Philips is currently working hand-in-hand with UPV and ILT on an initial approach for automatic machining code generation based on AI. The first trials primarily focus on a simplified case study (see below), aimed at laying the foundation for future machining codes on more complex workpieces like the Philips use case.



The initial automated machining code generation will be based on a simplified use case challenge for modelling. The model will predict code to machine layers from a sphere to create a flat surface with specific widths and will be trained and validated by using elementary trigonometric equations (box right).



Relation between parameters:

$d = R - h$

$d = R - \sqrt{R^2 - Rm^2}$

$R - d = \sqrt{R^2 - Rm^2}$

$(R - d)2 = R^2 - Rm^2$

$R^2 - (R - d)2 = Rm^2$

$Rm = \sqrt{R^2 - (R - d)2}$

$width = 2 * Rm$

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