D5.9 – Communication Kit – Final Update

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1 Project summary

In nearly every sector of industrial manufacturing a broad spectrum of **surface processing techniques** is used, e.g. for structuring, coating or polishing of aesthetical or functional surfaces. In the last years laser based surface processing techniques have made tremendous technical progress and are now entering industrial manufacturing on a broad scale. Reduced prices for short and ultra-short pulsed lasers and enhanced reliability promote especially laser structuring while new developments in the processing techniques are fostering laser polishing and laser thin-film processing.

Laser structuring can achieve small structures on a sub-millimetre down to micrometre scale (Figure 1 left). In particular, ultra-short pulsed lasers provide unique possibilities to manufacture smallest structures with highest demands on accuracy and quality. But for many applications the low throughput is still limiting this technique to the processing of moulding tools rather than the direct processing of the work piece itself.

Laser polishing is based on remelting a thin surface layer and smoothing the surface due to the surface tension. Starting from a metallic surface with an initial roughness of Ra = 1 - 10 µm laser polishing can achieve a roughness of Ra = 0.1 - 0.5 µm (depending on the material and its homogeneity). First industrial applications already show the potential of this new technology (Figure 1 middle) but there are still limitations which are preventing a broad industrial impact. The main limitations are a relatively low throughput and an enormous effort to establish this technique for new materials and 3D work pieces.

Laser thin-film processing is a powerful tool for improving the performance of technical components e.g. regarding wear, corrosion or electrical conductivity (Figure 1 right). Thin film processing is often a 2-step process involving the deposition of the film followed by a heat treatment. For heat treatment lasers represent a versatile alternative to conventional methods and enable processing of thermally sensitive substrates. Especially the ability to treat layers locally and selectively opens up new possibilities. Nevertheless, in many fields of application this technique requires long processing times and is not adaptable for complex three-dimensional components yet.

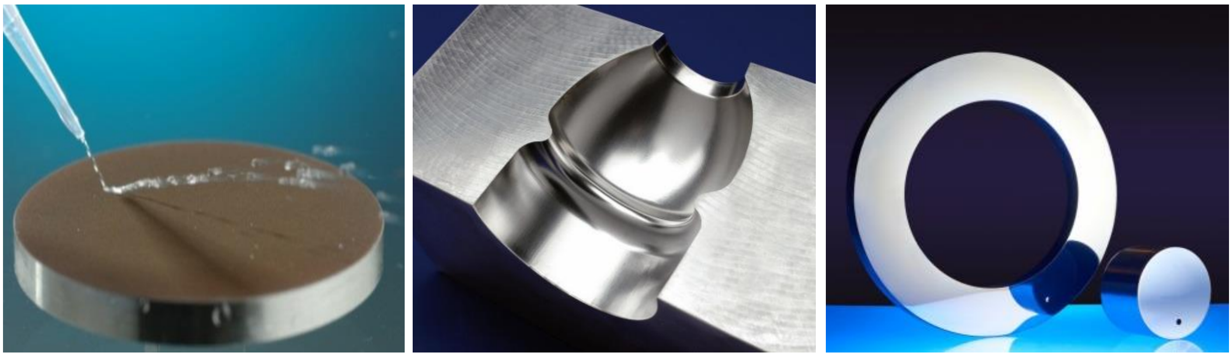


Figure 1: left: laser structured hydrophobic surface, middle: laser polished blow mould, right: automotive parts with laser functionalised thin-films for wear protection

In summary in many applications these laser based surface processing techniques already achieve highest precision and quality, but often the **throughput is limiting the industrial capability**.

State of the art for these and many other applications in laser surface processing is the utilization of one round laser beam (Figure 2 left). For processing in a meandering pattern the throughput TP (parts per time) can be calculated as

$$\boldsymbol{throughput\ TP = \left(t_{npt} + A \cdot \frac{n_{Steps}}{v \cdot dy \cdot n_{Laser}}\right)^{-1}}$$

t_{npt}: non-productive time

A: non-productive time

n_{Steps}: non-productive time

v: feed speed

dy: track offset

n_{Laser}: number of laser beams

To increase the throughput the process parameters v, dy and n_{Laser} needs to be increased while the non-productive time t_{npt} should be decreased. The idea of *ultra*SURFACE is to **increase the throughput** for laser surface processing by at least a **factor of 10** without any drawbacks in the quality of the processing results by using sophisticated optics for specific laser beam manipulation (Figure 2 right).

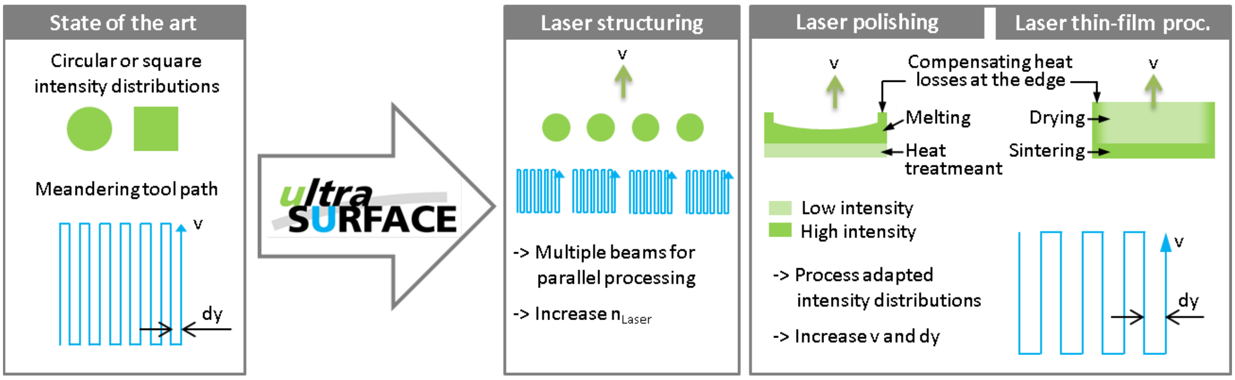


Figure 2: Overall concept of *ultra*SURFACE

Therefore **two different optics concepts** will be realized and combined with fast and synchronized mechanics, scanner and optics control. Everything is built into a machine specialized for fast laser surface processing.

Optics Concept 1 refers to a dynamic and flexible **beam-shaping** approach with piezo-deformable mirrors which enables the realization and the fast adaption of application specific intensity distributions. This will allow significant increase in feed speed and track offset and therefore in throughput.

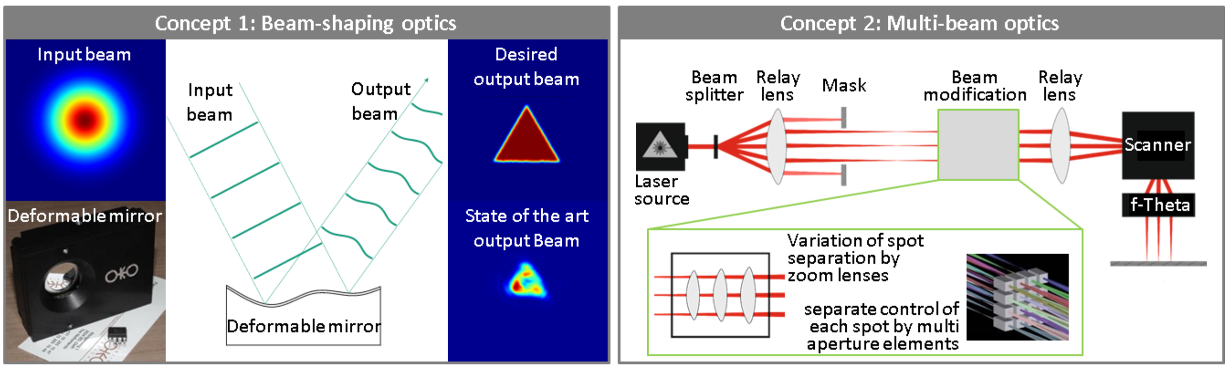


Figure 3: Optics concepts of *ultra*SURFACE

Optics Concept 2 is a **beam-splitting** approach which allows simultaneous processing with multiple laser beams and thus a significant increase in throughput.

For both concepts the implementation of prototypes is planned as well as their industrial validation in different fields of application (laser structuring, laser polishing, laser thin-film processing).

2 Impact

*ultra*SURFACE will provide **innovative Ultra Dynamic Optical Systems** and will therefore be an **enabling technology for the European industry** in the field of high throughput laser surface processing. In nearly every sector of industrial manufacturing, surfaces of components are processed e.g. polished, coated, or structured. *ultra*SURFACE focuses on the improvement of optical systems, real-time adaption and processing strategies for high throughput laser surface processing and thus addresses the entire market of laser industrial manufacturing.

Today, existing laser surface processing systems do not fulfil the requirements of **throughput and flexibility** demanded by the industries. *ultra*SURFACE will enhance both throughput and flexibility significantly. Thus, laser-based processing will **exceed the break-even point** in comparison with conventional surface processing techniques. This will be a breakthrough for high throughput laser processing in nearly all branches of industrial manufacturing.

The impact of *ultra*SURFACE will have strong influence on the following branches of industries:

- **Automotive Industry**: High quality products in connection with low costs are of great importance. This results in the requirement of processes with high throughput.
- **Mechanical Engineering**: Surfaces need to be processed e.g. to ensure wear resistivity, corrosion resistivity or frictional behaviour. Surface shapes are often freeform surfaces.
- **Consumer Products**: Outstanding surface qualities are necessary for aesthetical and/or technical reasons.

The impact of *ultra*SURFACE provokes a significant reduction of manufacturing costs and time and strongly enhances throughput. The processing costs will expectedly be reduced by at least 50 % and production time will expectedly be decreased by at least 70 % in comparison with conventional techniques. This high performance improvement makes **laser-based surface processing systems commercially efficient**. Regarding to this benefit, *ultra*SURFACE will have strong impacts on the European market for laser surface processing systems which divides into the following two sectors:

- Surface Processing Machines: To keep up with the competition laser-based surface processing machines need to be most cost-saving. *ultra*SURFACE paves the way for the introduction of laser-based surface processing machines in the European and world market due to reduced manufacturing costs, high throughput and high manufacturing quality.
- Optical Systems: Optical systems with dynamic and synchronized 3D-adaptability are necessary for an increase of throughput and flexibility in surface processing. *ultra*SURFACE will transfer research results to industrial applications.

The **market share of optical systems for laser material processing** 5 years after project termination is expected to increase from 470 million Euros to 940 Million Euros.

Figure 4: Current polishing situation and galvanic techniques for surface processing

Furthermore *ultra*SURFACE will improve working conditions in the sector of surface processing by

- reducing noise disturbance and dispersible dust – especially heavy metal dust
- no usage of chemicals solutions
- reducing CO2 emission up to 80 %.

Thus the project will have a significant contribution to promote green manufacturing in Europe.

3 Partners

No.	Short Name	Participant organisation name	Country
1	FHG-ILT	Fraunhofer Gesellschaft Fraunhofer Institute for Laser Technology ILT	Germany
2	RWTH-TOS	RWTH Aachen University Chair for Technology of Optical Systems	Germany
3	UNITECH	Unitechnologies SA	Switzerland
4	PULSAR	Pulsar Photonics GmbH	Germany
5	NEWSON	Newson Engineering Naamloze Vennootschap	Belgium
6	OKO	Flexible Optical BV	Netherlands
7	HOLO-OR	HOLO-OR LTD	Israel
8	SCHAEFFLER	Schaeffler Technologies GmbH & Co. KG	Germany
9	PROCTER-GAMBLE	Procter & Gamble Manufacturing GmbH	Germany
10	GEMUE	GEMÜ Gebr. Müller Apparatebau GmbH KG	Germany

4 Technical achievements and exploitation

The goal of ultraSURFACE is the increase of throughput for laser material processing in the case of laser polishing, laser thin-film processing and laser micro structuring. Therefore two optical systems have been developed: beam-shaping optics and beam-splitting optics.

The concept for the beam-shaping optics is based on a shaping of the raw Gaussian beam via a DOE (diffractive optical element) and the adaption to the work piece geometry using a deformable mirror. By this an individually shaped intensity distribution should be achieved with keeping the process conditions constant also on freeform surfaces. In case of the multi-beam optics a DOE is used for splitting a Gaussian beam into four equal beams. Each of the four beams is individually controllable in all three Cartesian directions via using a spot position control unit. For the lateral position this is achieved by using two rotating glass plates. For the vertical shift (parallel to the optical axis) this is done by using a movable lens. Both optics are mainly controlled by the scanner controller to be synchronized with the current scanner position. In case of the beam-shaping optics the scanner controller is communicating with the controller of the deformable mirror.

For both optics a prototype has been developed and characterized.

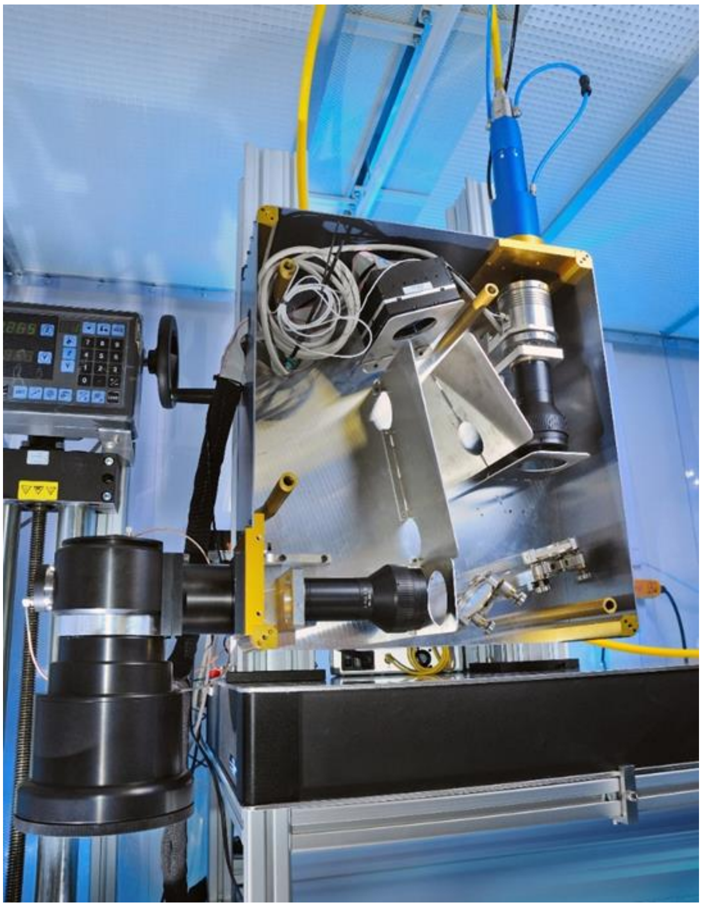


Figure 5: Beam-Shaping optics in the lab

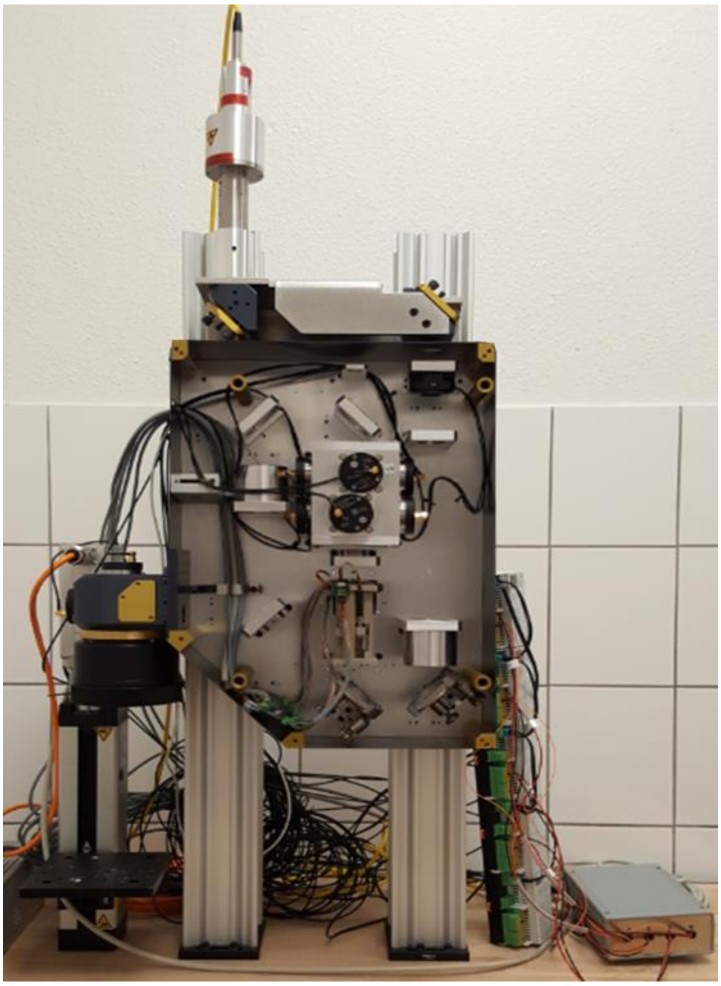


Figure 6: Multi-Beam optics in the lab

With the Beam-Shaping optics, it was not yet possible to process 3D parts of the end-users, as different problems arose, which could only partially be solved within the scope of the project. The following problems could not be solved within the framework of the project and currently prevent the use of Beam-Shaping optics:

- Originally not planned realization of the intensity distribution via a DOE, which must be rotatable, so that the intensity distribution can be aligned to the scan direction, represents a clearly more complex approach (both for the adjustment and for the control of the system). One problem is that the intensity distribution did not rotate around its center, so that a meander-shaped laser polishing was not possible.

Design and manufacturing of additional components for beam guidance in order to optimize/correct the alignment of the laser beam into the hollow shaft motor was done, but no longer integrated and adjusted into the Beam-Shaping optics within the scope of the project.

- Hysteresis effect of the deformable mirror (inherent to the piezo-materials) makes a feedforward control challenging and will require modification of the mirror controller.

- Intensity distribution does not meet the requirements, especially for thin-film applications.

Thus the Beam-Shaping optics needs further improvements.

In order to give the end-users at least the opportunity to evaluate the quality of laser-processed components, other laboratory set-ups (state of the art) were used to process 3D parts.

For the 3D-processing a laser machine was developed by the company Unitechnologies (see figure 5). After some improvements the Multi-Beam optics could be integrated into the 5-axis machine and parts of the end-users could be laser structured successfully (see figure 6). The main platform features are the measurement of the real part with a tactile probe (referencing on the work piece) and the continuous five axis processing. Subsequently, various components were laser structured with the integrated multi-beam optics (see figure 7).

Figure 7: Laser machine tool

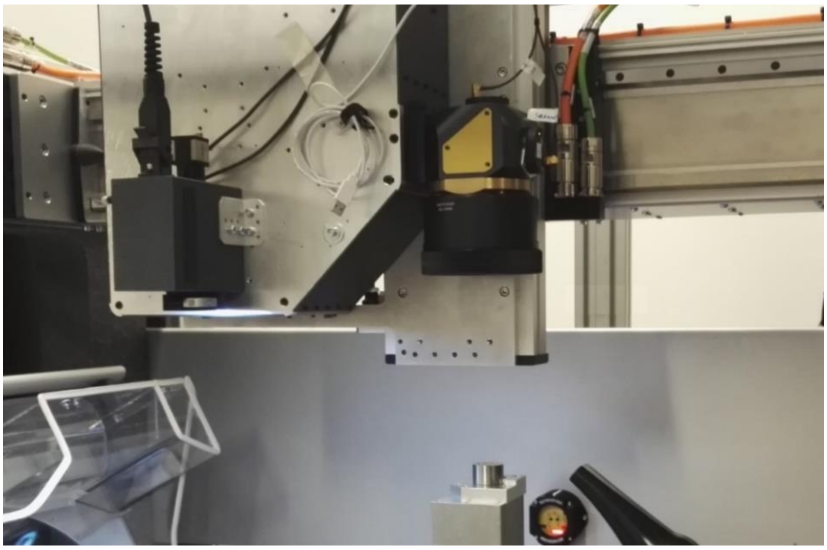


Figure 8: Integrated multi-beam optics in the laser machine tool

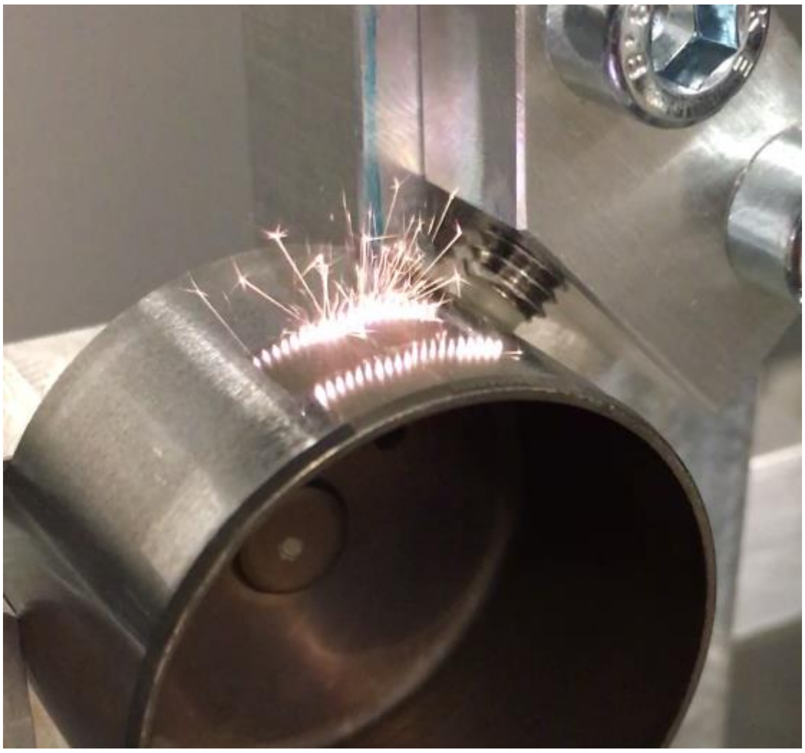


Figure 9: Laser structuring of a part provided by an end-user in the project using the multi-beam optics integrated in the developed machine tool

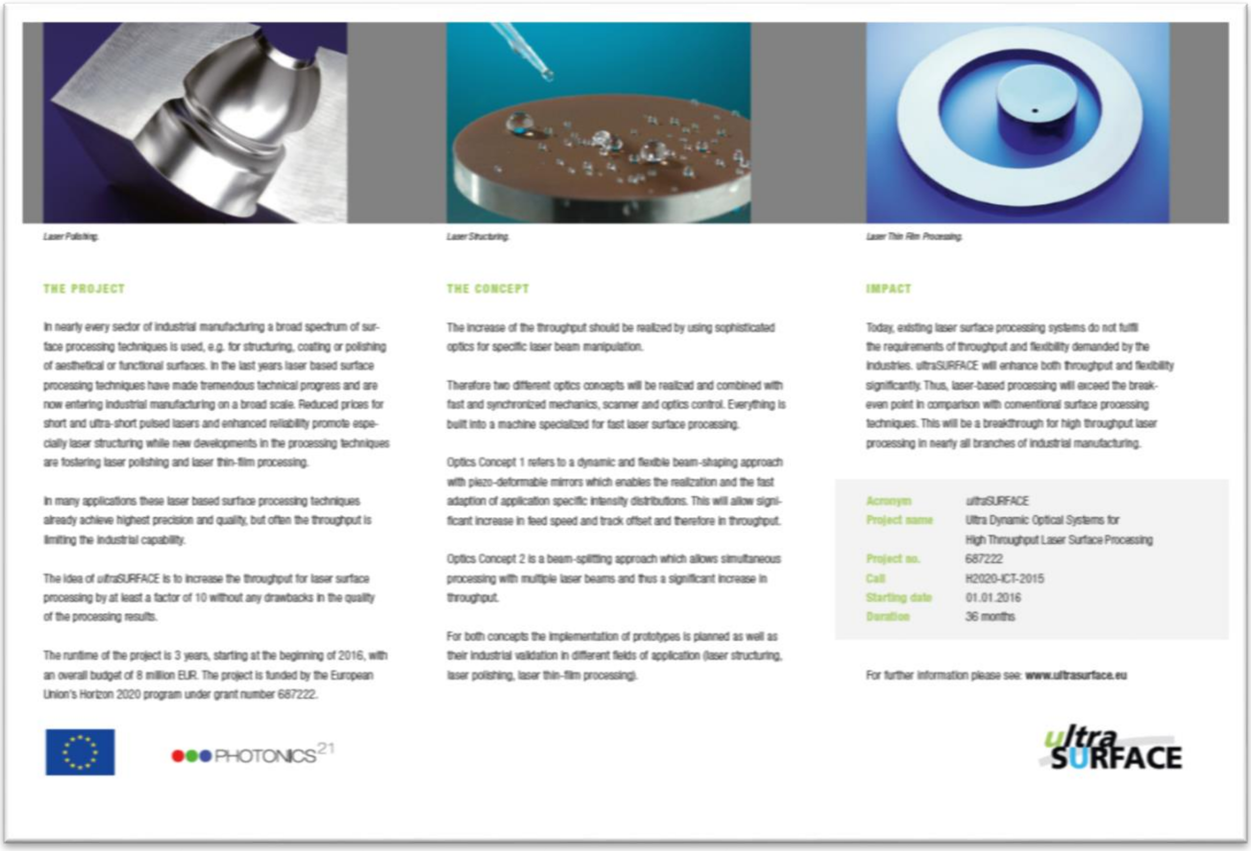
Different application tests on the laser structured parts were performed at the end-users Schaeffler and Procter&Gamble and showed promising results. For both applications of the end-users a reduction of the processing time by a factor of 3 was achieved using the Multi-Beam optics. Although the goal of a 10-fold higher throughput is not achieved with this example product, the cost savings are nevertheless considerable. For the consideration of a concrete case a cost reduction of 58 % results.

In sum three prototypes were built within ultraSurface (Beam-Shaping optics, Multi-Beam optics, 5-axis laser machine tool). The commercial exploitation of the Beam-Shaping optics is not possible with the current prototype result, as the basic goals could not be demonstrated. However, the market potential for a high average laser power beam shaping system is still very attractive for a lot of different applications (polishing, additive manufacturing, welding, surface treatment). Thus further research especially on the deformable mirror is planned in order to increase the TRL-level of this technology. The successfully tested Multi-Beam prototype will be used for marketing activities to show its possibilities for different applications like micro-structuring or drilling. Furthermore a product version of the Multi-Beam optics will be developed, produced and distributed with an increased number of laser beams. Also the work of the 5-axis laser machine tool was successfully demonstrated. This machine tool is on the one hand an independent product and on the other hand can be adapted and used for various 3D laser processes.

Additionally several products developed or further developed by the SMEs as part of the project are already being sold. In addition, a new company is planned regarding a job shop for laser surface processing based on the project results.

5 Additional communication material

5.1 Project flyer



Laser Polishing.

Laser Structuring.

Laser Thin Film Processing.

THE PROJECT

In nearly every sector of industrial manufacturing a broad spectrum of surface processing techniques is used, e.g. for structuring, coating or polishing of aesthetical or functional surfaces. In the last years laser based surface processing techniques have made tremendous technical progress and are now entering industrial manufacturing on a broad scale. Reduced prices for short and ultra-short pulsed lasers and enhanced reliability promote especially laser structuring while new developments in the processing techniques are fostering laser polishing and laser thin-film processing.

In many applications these laser based surface processing techniques already achieve highest precision and quality, but often the throughput is limiting the industrial capability.

The idea of *ultraSURFACE* is to increase the throughput for laser surface processing by at least a factor of 10 without any drawbacks in the quality of the processing results.

The runtime of the project is 3 years, starting at the beginning of 2016, with an overall budget of 8 million EUR. The project is funded by the European Union's Horizon 2020 program under grant number 687222.

THE CONCEPT

The increase of the throughput should be realized by using sophisticated optics for specific laser beam manipulation.

Therefore two different optics concepts will be realized and combined with fast and synchronized mechanics, scanner and optics control. Everything is built into a machine specialized for fast laser surface processing.

Optics Concept 1 refers to a dynamic and flexible beam-shaping approach with piezo-deformable mirrors which enables the realization and the fast adaption of application specific intensity distributions. This will allow significant increase in feed speed and track offset and therefore in throughput.

Optics Concept 2 is a beam-splitting approach which allows simultaneous processing with multiple laser beams and thus a significant increase in throughput.

For both concepts the implementation of prototypes is planned as well as their industrial validation in different fields of application (laser structuring, laser polishing, laser thin-film processing).

IMPACT

Today, existing laser surface processing systems do not fulfil the requirements of throughput and flexibility demanded by the industries. ultraSURFACE will enhance both throughput and flexibility significantly. Thus, laser-based processing will exceed the break-even point in comparison with conventional surface processing techniques. This will be a breakthrough for high throughput laser processing in nearly all branches of industrial manufacturing.

Acronym	*ultraSURFACE*
Project name	Ultra Dynamic Optical Systems for High Throughput Laser Surface Processing
Project no.	687222
Call	H2020-ICT-2015
Starting date	01.01.2016
Duration	36 months

For further information please see: **www.ultrasurface.eu**

PHOTONICS21

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You can download the project flyer under www.ultrasurface.eu → Dissemination Activities → Project flyer.

6 Project summary is written by a non-scientist to reflect better the planned contents as described in the Description of Action

The following project summary is written by a non-scientist.

ultraSURFACE - Efficient laser surface treatment

Whether for functional structuring, coating or polishing: lasers have proven to be very advantageous tools in many areas of industrial production, which have significantly increased the economic efficiency and robustness of processes, especially in recent years. However, previous laser applications in industrial surface processing often have limited throughput or are not suitable for more complex adaptations.

The project ultraSURFACE, which is funded by the European Union, focuses on the optimization of optical systems with dynamic 3D applicability and the development of strategies for high-throughput laser-based production processes. At the same time, the project also contributes to making production in Europe more environmentally friendly. The developed concepts reduce noise, dispersion dust, the use of (poisonous) chemicals and improve the CO2 balance by reducing emissions. Ten partners are participating in the project, which is coordinated by the Fraunhofer Institute for Laser Technology ILT in Aachen.

New optical concepts for increased throughput

In the ultraSURFACE project, scientists and partners from industry are developing two new optical concepts that enable individually adapted laser beam manipulations and increase throughput by a factor of 10 compared to conventional processes. Beam-shaping and beam-splitting optics for the laser are used for this purpose. For laser polishing and coating, the beam-shaping optics can be used to individually adjust the intensity profile of the laser beam to local surface conditions. In addition, laser microstructuring with beam-splitting optics allows the surface to be processed with several individual beams at the same time.

The aim of the ultraSURFACE project is also to demonstrate the usability in production - the developed technologies are later integrated into various industrial applications by means of corresponding prototypes. The new concepts are tested and evaluated during laser polishing, laser thin-film processing and laser microstructuring. In addition to high-quality products for the automotive industry or mechanical engineering in general, the concepts developed are also suitable for the manufacture of consumer products. The new concepts of the ultraSURFACE project thus offer a high potential for many industries - not only in the European laser market.

7 Press Release - A generally understandable description of the project from a non-scientific point of view

You can download the press release under www.ultrasurface.eu → Dissemination Activities → Publications