# Efficient ablation strategies and quality assurance for structuring big surfaces by an ultra-short-pulse laser

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**Abstract**

Owing to the high flexibility when using a laser beam as a tool, its field of application grows more and more. In case of micro structuring of metal components especially the use of ultra short laser pulses offers a high potential for precise and high quality results. However the economical application in an industrial surrounding is still affected by different issues, e. g. a lack of process efficiency. In this work, different factors and their influence on the ablation process are investigated for a improvement of the process efficiency for structuring micro-sized dimple structures on big metallic surfaces. To achieve this goal the repetition rate and the pulse strategy of the laser have to be in focus. Furthermore the interaction between consecutively produced holes and the heat accumulation for each hole were particularly taken into consideration. To constantly ensure the capability of the ablation process it is essential to measure and analyse the results of the process. This sets up the focus on a fast and reliable quality assurance of the ablated microstructures. Therefore this paper covers an automated evaluation approach for optical measurement data of micro-structured surfaces in addition to the manufacturing approach.

## 1. Introduction

Process efficiency is one major drawback when working with a laser compared to for example mechanical structuring processes. Besides different possibilities to optimize the machine technology (faster scanner systems, beam splitting) the process itself has an optimum parameter field which is dependent on the boundary conditions, e.g. material or wavelength of the laser.

## 2. Experimental Set Up

The used laser was a Trumpf TruMicro5050 with 6 ps pulse length, a maximum repetition rate of up to 800kHz with a max. pulse energy of up to 62,5µJ at the laser outlet and about 56µJ resulting on the surface, which is considerd to be 100% pulse energy in the following. The set-up can be seen in Figure 1 (left). The probes were made of stainless steel (1.4301) sheets with 1mm thickness and were analysed after the experiments by a confocal measurement system (Nanofocus). Based on pre-experiments the factors like shown in figure 1, b) were varied.

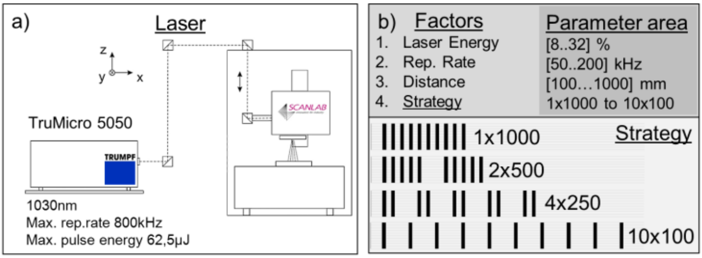


Figure 1: a) Laser set-up, b) experimental parameters

## 3. Results

The MPEE (multi-pulse enhancement effect), which shows a less deeper first dimple in a row, like observed in Fu et al. when structuring silicon is recognized as neglible in this work. It is presumed that this is based on the lower mean power of up to 1W in this work compared to 3,5W in [1]. Additionally with the use of a nanosecond laser and a high fluence the autors there worked solely in the thermal ablation regime. In this context the influence of the distance between the structures was neglible in the chosen parameter field. Besides the repetition rate which is known to have an influence on the process efficiency [2] the strategy was found out to have an impact too, like it can be seen in figure 2. Because the total amount of pulses at each position is constant at 1000, the strategy is represented as a factor of repetitions from 1x1000 to 10x100. For each parameter regime a saturation can be obeserved when splitting the 1000 total pulse bursts into 10 bursts with 100 pulses each. The difference between the average values ranges from ~23% to 30% for the lower pulse energies while the difference ist ~12% for 32% Pulse energy. We assume particle shielding in this regime, contrary to [3] where particle shielding is assumed to take place at 200 kHz upwards. This could explain this effect, as there are some pulses supposed to hit the surface without being influenced by the developing particle cloud.

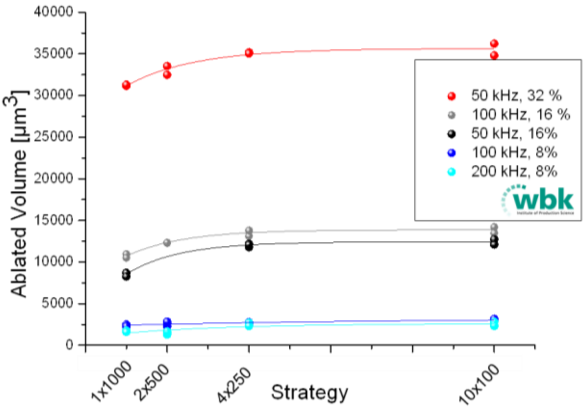


Figure 2: Influence of the strategy on the ablated volume

From the standpoint of process efficiency the splitting of the 1000 pulses at once to at least 4 bursts in this case leads to the highest ablation volume, which equals the trend of the resulting structure depth because the diameter does not change considerably.

## 4. Quality Assurance

For a reliable calculation of function-related quality indicators, it is essential to accurately detect and evaluate the microstructure on the surface. Due to the presence of other structures like grinding groves with an identical depth-profile on the surface, the measurement data analysis faces difficulties when it comes to automatically detect and describe the microstructures. The methodology developed at the wbk – Institute of Production Science is able to automatically evaluate the micro-structured surfaces. The first stage of the two-stage methodology is termed single point analysis. It is used to automatically mark the regions of interest in the measurement data. The single point analysis evaluates the mean value and the variance of the distances between the measurement points in all spatial directions. The aim of the second stage is to automatically detect forms in the processed digital image of the surface measure-ment. In case of circular microstructures, the object recognition is performed in order to extract the radius and the circle centre point. After decomposing the input data from the first stage into distinct accumulator spaces, the Hough transformation assigns circles with a defined radius to all object points in the picture. Each accumulator space is characterized by a different radius of the assigned circles. A single local maximum in the Hough space, marked by the intersection of the assigned circles, is only observable, if the radius of the assigned circles is equal to the unknown radius of the microstructure. This local maximum represents the located circular object, characterized by its centre point. The radius of the real object can be deduced from the value of the specific accumulator space, the local maximum is located in.

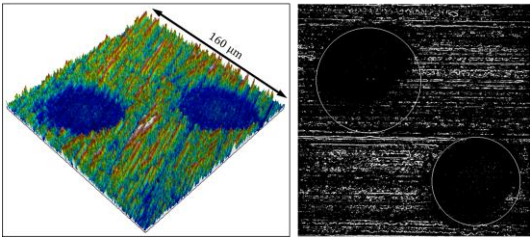


Figure 3: Input measurement data (left), processed data with two objects (right)

Figure 3 shows the results of the three-stage methodology for the automated detection of microstructures on preliminary ground technical surfaces. The processed data with two recognized objects are displayed on the right hand side. The micro-dimples on the surface were successfully found and marked by the algorithm, even though the shape of the micro-cups is more like an ellipsoid, due to process-caused form deviations in this case.

## 5. Conclusion

Due to intensive preliminary ablation tests a reasonable range of parameters was located for the production of holes with a minimum volume of melt. The influence of the distance between the holes is pointed out to be negligible. Therefore the ablation process can be sufficiently optimized by regarding the repetition rate and the pulse strategy. A quality assurance is possible by an automated methodology developed at wbk.

**References:**

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