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Focal point determination in laser micromachining via ablation acoustic response

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Introduction

The relative position of the workpiece to the focus plane is essential in laser processing. As the distance from the focal point increases, the intensity distribution changes, the cross-sectional area of the laser spot increases, and as a result, the machining effects obtained are altered. This is particularly relevant in laser micromachining applications of brittle materials, which are especially sensitive to parameter variations. The accurate and conscious positioning of the workpiece in relation to the focal point is a technical challenge on which the quality of treatment depends. To address this problem, an acoustic method for determining the position of the focal point is presented in this study. The proposed method facilitates the audio signal resulting from laser ablation and allows to eliminate microscopic analysis, significantly speeding up and improving the focussing operation.

Materials and methods

The experiments were carried out using an ultra-short pulse laser system Duetto (*Lumentum*, ex. Time-bandwidth, San Jose, USA). The laser operated at a wavelength of 532 nm, with pulse duration of 10 picoseconds and repetition rate of 250 Hz in order to separate ablation response signals in time domain. The output pulse energy was set to 70 µJ. The laser system was equipped with a galvo scanner and a f-theta lens with a focal length of 160 mm. A matrix of 9 craters was performed for each position, and every crater was machined with a train of 10 pulses in total. Positioning in the Z axis was performed by the MLJ050 / M translation stage (*Thorlabs*, Newton, USA) with a positioning accuracy of less than 30 µm. Acquisition and calculation of the audio signal were performed by a self-developed software, in the frequency range of 60Hz – 18kHz. The laser-ablated craters were measured with a LEXT OLS4000 scanning confocal microscope (*Olympus*, Shinjuku, Japan) and further investigated as a 3D point cloud in TalyMap 7 Gold software (*Taylor Hobson*, Leicester, England).

Results and discussion

The results revealed a clear correlation between laser focal position and acoustic signal amplitude. As the substrate surface approached the focal point, the amplitude of the acoustic signal increased and finally saturated within the Rayleigh length. A corresponding chart can be seen in Fig. 1.

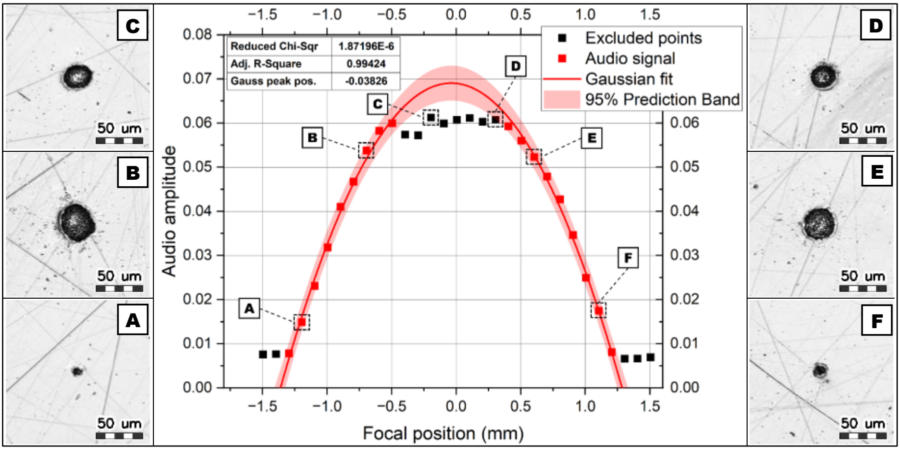

Fig. 1. Chart of the audio signal against the focal position, fitted with a Gaussian function. Letters show the corresponding top view of the laser-ablated craters

This phenomenon enables to estimate focal point position based on a Gaussian fit, which peak indicates position of the smallest laser spot size.

Conclusions

The ablation acoustic response can be utilised efficiently for the determination of the focal point position in the laser micromachining. In comparison to volume and depth methods, the proposed solution does not require microscopy measurements, can be done directly at the laser station and generates the same results with absolute error less than 40 µm. Although further investigations shall be conducted to extend utilisation over various material types.