# Master's Thesis Engineering Technology

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# Investigation of process disturbances in femtosecond laser texturing of stainless steel


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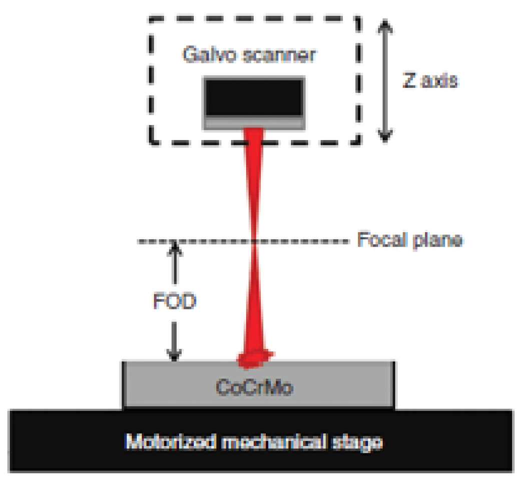

Figure 1: Visualisation of the FOD disturbance [2].

## Situation

In cooperation with the Manufacturing research group from the school of Engineering in Birmingham, research is conducted to examine two main disturbances for laser processing: The Focal Offset Distance (FOD) and the Beam Incident Angle (BIA), shown in Figures 1 and 2. This has not been done for femtosecond lasering yet. The effect of these disturbances is needed for laser manufacturers and users to partition 3D/free form surfaces, so that optimal operating margins can be created to determine optimal processing speeds for industrial applications [1].

The aim of this research is to examine these disturbances to provide this information for the partitioning of 3D/free-from surfaces. Furthermore, a model for laser ablation for femtosecond lasering is evaluated, and suggestions given to improve and expand the model, to include the mentioned disturbances.

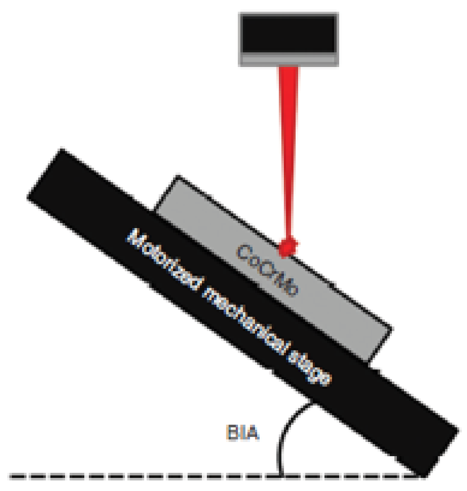

Figure 2: Visualisation of the BIA disturbance [2].

## Methodology

### Experiments

For the experimental examination of the disturbances, a line grid is used. This line grid is the repeated in a matrix shape for two different laser process parameters: scanning speed and number of layers, i.e. the number of times the laser passes. This matrix (fig.3) is repeated for different values of the disturbances. Scans are then made of these matrices and used to examine the depth and Full Width at Half Maximum (FWHM).

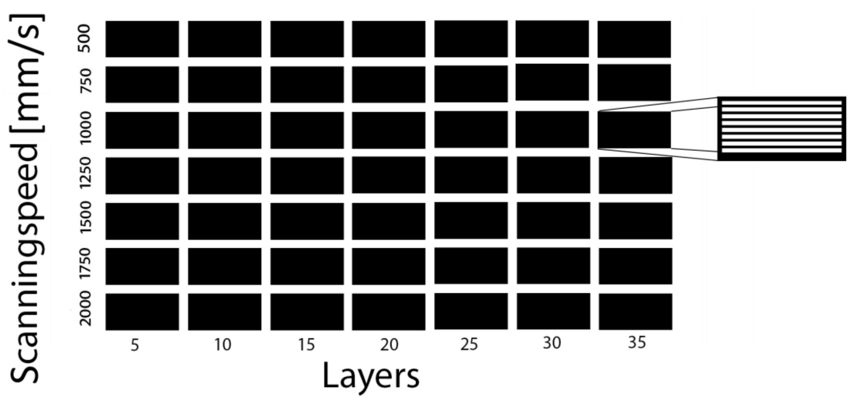

Figure 3: Process parameter matrix for lasering using a line pattern cell.

### Modelling

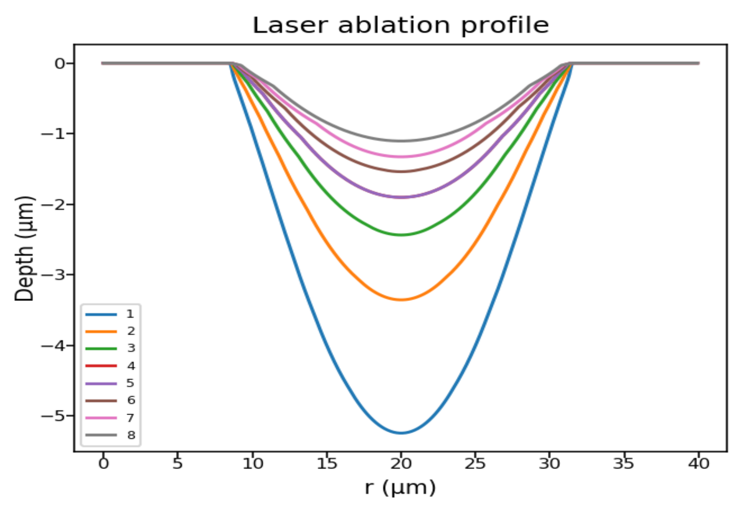

Figure 4: Example of calculated ablation profile from the model.

For the provided model (fig.4) a first comparison between the experimental data and the model data was made. The used model parameters were taken from the literature [3]. The model does not give the depth of FWHM values, so these were measured by hand on printed images of the model.

## Results

### FOD

The higher the FOD, the lower the groove depth as can be seen in Figure 5. This is as a result of the decrease in fluence, i.e. energy density. For very large FOD values (2-2.5mm) there is almost no difference in depth for different process parameters. The FWHM increases gradually with higher FOD, because of the beam spot increase.

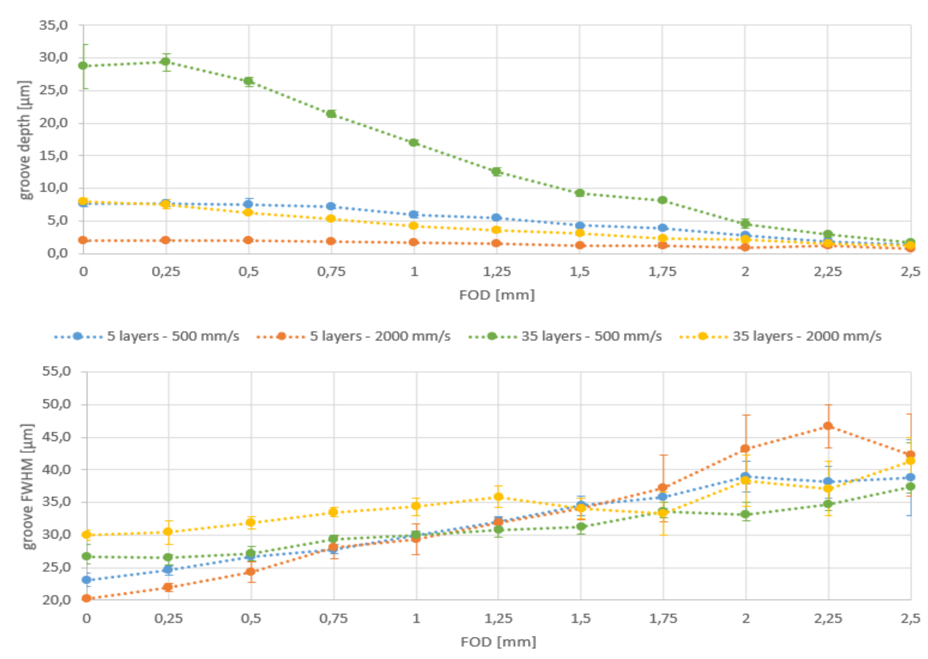

Figure 5: Depth and FWHM as function of FOD.

### BIA

The BIA has a similar effect on both depth and FWHM. When a BIA is introduced, the depth and FWHM converge to a certain value, as shown in Figure 8. The depth convergence is dependant on the number of layer, whereas the FWHM converges to one point for all layers. This also indicates that the influence of scanning speed has no effect on the groove dimensions anymore.

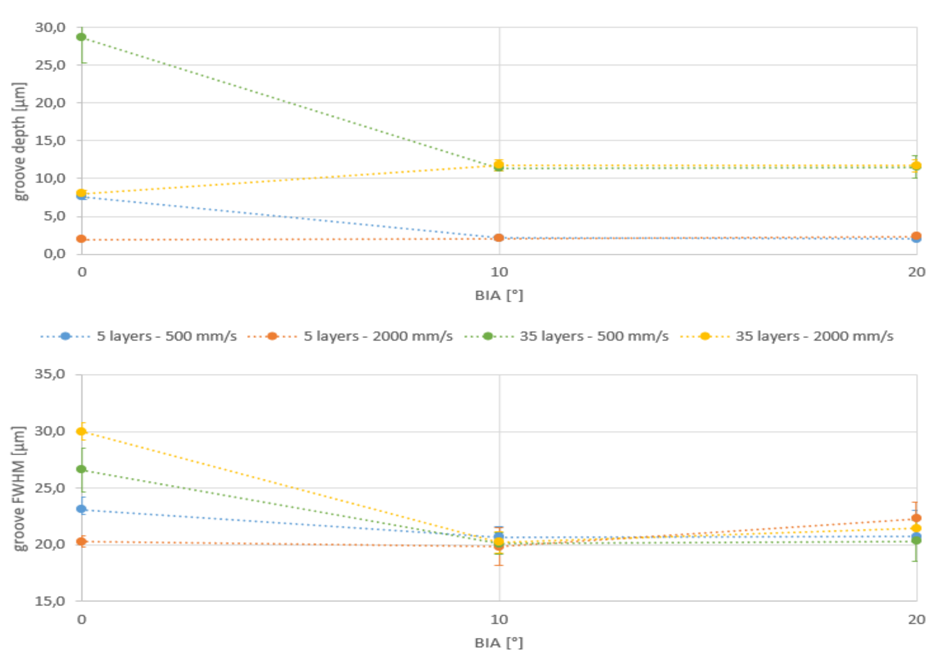

Figure 8: Depth and FWHM as function of BIA.

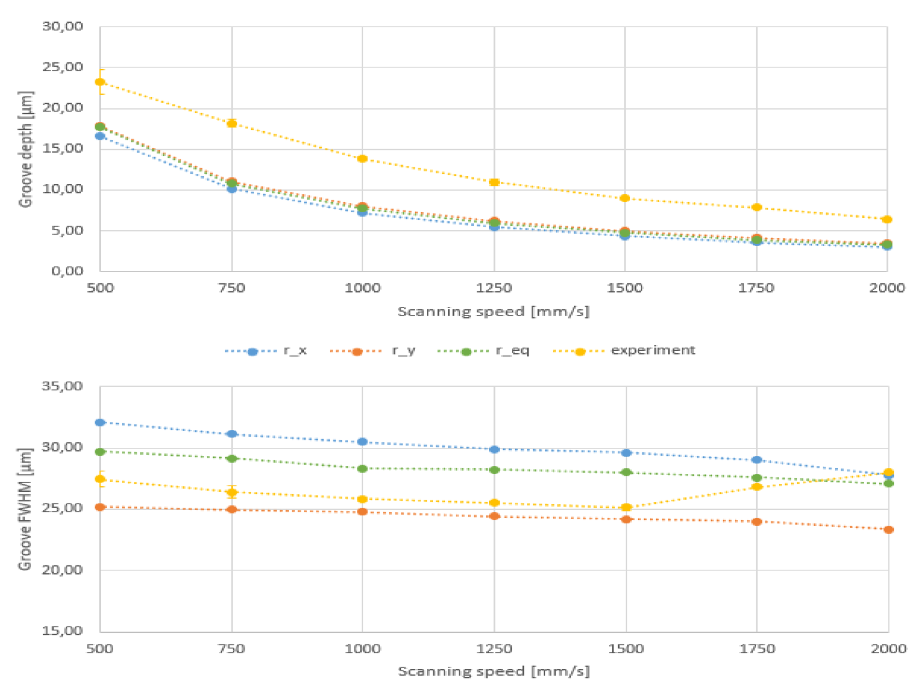

Figure 6: Comparison of model and experimental depth and FWHM.

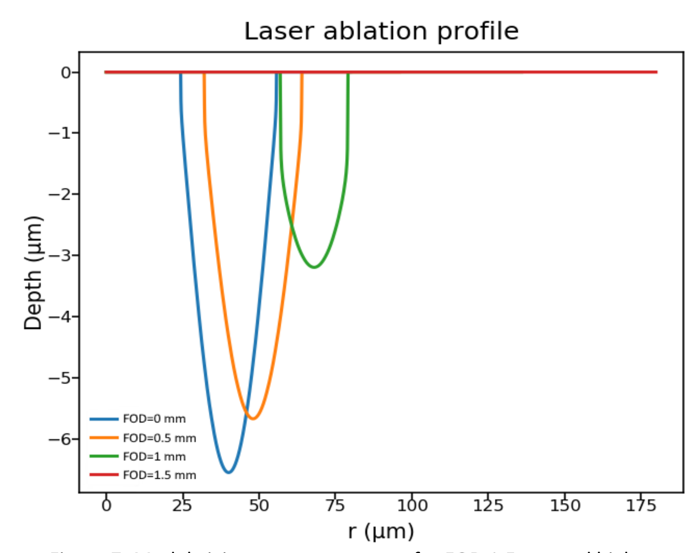

Figure 7: Model giving no more grooves for FOD 1.5mm and higher.

### Comparing model with experiments

Because the model assumes no FOD or BIA, only this sample was compared. The laser beam is elliptical in shape, so all radii are used to create a margin to compare to the experiment. The experimental values however were larger than the model values, as Figure 6 shows. When examining other process parameters, the measured depth was consistently larger than the model values. The FWHM however, was sometimes within these margins.

### No model ablation

When examining the radii of the laser beam for high fluences, the model results became zero, i.e. there is no ablation (fig. 7). The experiments however clearly show grooves are still lasered on the sample.

### Model suggestions

The suggestions to change and expand the model are mainly based around the implementation of the disturbances. To include the FOD, the model should include an option to implement the beam propagation, or an input for fluence, instead of calculating this. The first step to implement a BIA, is the change of beam spot shape because of angled projection.

## Conclusions

The disturbances have a large impact on the groove dimensions. By examining these disturbances, their effects can be used for partitioning of complex 3D/ free form surfaces to create optimal operating margins so optimal processing speeds for industrial applications can be determined.

It was concluded that either the model values or the calculating of the ablation threshold needs to be checked and verified. Also some improvements for the model can reduce the number of experiments needed to be done in the future, or even be implemented in 3D CAD calculations.

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Prof. Sylvie Castagne
Prof. Stefan Dimov
Prof. Richard hall


**References**

[1] A. Batal, A. Michalek, P. Penchev, A. Kupisiewicz, S. Dimov, and 1, "Laser processing of complex surfaces: polishing and texturing of 3D printed Ti-6Al-4V spherical shells," Edgbaston, Birmingham, 2020.

[2] A. Batal et al., "Effects of laser processing conditions on wettability and proliferation of Saos-2 cells on CoCrMo alloy surfaces," Advanced Optical Technologies, pp. 1–12, 2019.

[3] W. Liu, M. Sun, Y. Guo, Z. Jiao, R. Wu, and X. Pan, "Ablation characteristics of aluminum alloy and stainless steel induced by picosecond laser pulses," in Pacific Rim Laser Damage 2019: Optical Materials for High-Power Lasers, 2019, vol. 11063, p. 44.


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