International Conference on Advanced Optical Technologies
University of Erlangen-Nürnberg, March 13th – 15th 2019

Towards a better understanding of dynamics in metal processing with ultrashort laser pulses - numerical simulations

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The processing of metal with ultrashort lasers is nowadays well established in industry, it is an expanding and continuously developing field with still more, so far not usable potential due to incomplete process understanding.
The ablation of metal with ultrashort laser pulses is determined by nonlinear absorption processes leading to an enhanced energy coupling into the workpiece with highly reduced heating compared to the use of longer pulses. It permits a high quality treatment which is the reason for the strong presence in industry. Besides micro-drilling and ablation, 2.5D surface structuring and its functionalisation are already utilised, although the formation process of the appearing self-organised structures is only partly known. A proper modelling of the absorption of ultrafast laser pulses, and the subsequent dynamics in the workpiece could contribute fundamentally to a detailed study and thus to a better understanding of the whole process. So far, there is no satisfying simulation of the complex fluid dynamic interactions, processes under extreme physical conditions regarding short timescales and high peak powers. Existing approaches are not able to fully describe the process dynamics due to strong simplifications or a high computing time.
Currently, we are working on a physical multi-phase simulation for ablation with ultrashort laser pulses, based on a CFD-model in use for short pulses and built up with the software package OpenFOAM. There are promising first results, well-fitting to experimental results and theoretical knowledge, after respecting the two-temperature-model and the temperature dependence of material parameters to adapt the heat conduction as well as implementing nonlinear, temperature-dependent absorption and a changed temperature distribution in the workpiece. A future prospect is to expand the model further to achieve numerical results showing the presence of self-organized structures like LIPSS and CLP and to gain in this way more knowledge and control of their formation.
Numerical modelling is an efficient method for process optimization and quality improvement since it allows simulating series of measurements with great parameter variations and provides an insight into so far experimentally inaccessible processes. Thus, it contributes to a better process understanding, optimized process parameters and time and resource efficient production.

References

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