Tailored Sub-micrometer Periodic Surface Structures via Ultrashort Pulsed Direct Laser Interference Patterning

F. Fraggelakis 1, G. D. Tsibidis 1 and E. Stratakis 1,2

1. Institute of Electronic Structure and Laser (IESL), Foundation for Research and Technology (FORTH), N. Plastira 100, Vasilika Vouton, 70013, Heraklion, Crete, Greece
2. Department of Physics, University of Crete, 71003 Heraklion, Greece

Direct Laser Interference Patterning (DLIP) with ultrashort laser pulses (ULP) represents a precise and fast technique to produce tailored periodic sub-micrometer structures on various materials. In this work, an experimental and theoretical approach is presented to investigate the previously unexplored fundamental mechanisms for the formation of unprecedented laser-induced topographies on stainless steel following proper combinations of DLIP with ULP. The combined spatial and temporal shaping of the pulse increases the level of control over the structure features whilst it brings new insights in the structure formation process. DLIP is aimed to determine the initial conditions of the laser-matter interaction by defining an ablated region while double ULP are used to control the reorganisation of the self-assembled laser induced sub-micrometer sized structures by exploiting the interplay of different absorption and excitation levels coupled with the melt hydrodynamics induced by the first of the double pulses. A multiscale physical model has been developed to correlate the interference period, polarization orientation and number of incident pulses with the induced morphologies. Special emphasis is given to electron excitation, relaxation processes and hydrodynamical effects that are crucial to the production of complex morphologies. Results are expected to derive new knowledge of laser-matter interaction in combined DLIP and ULP conditions and enable enhanced fabrication capabilities of complex hierarchical sub-micrometer sized structures for a variety of applications.

Fig.1. Experimental and theoretical data on stainless steel irradiation by spatially shaped double femtosecond laser pulses. Results are illustrated for two-DLIP (first row) and four DLIP (second row).

References

Fraggelakis F., Tsibidis G.D., Stratakis E., ‘Sub-micrometer periodic surface structure formation with ultrashort pulsed Direct Laser Interference Patterning of solids’, (https://arxiv.org/abs/2008.04275)