LASER-INDUCED PERIODIC SURFACE STUCTURES, MECHANISMS, APPLICATIONS, AND UNSOLVED PROBLEMS

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Abstract. *Laser-induced Periodic Surface Structures* (LIPSS, ripples) are a universal phenomenon and can be generated in a contactless, single-step process on almost any type of solid upon irradiation with intense laser pulses (Bonse et al. 2012). They represent a (quasi-)periodic modulation of the surface topography in the form of a linear grating and are typically formed in a "self-ordered" way in the focus of a laser beam. Thus, they are often accompanying laser material processing applications. The structural sizes of LIPSS typically range from several micrometers down to less than 100 nanometers – far beyond the optical diffraction limit – while their orientations exhibit a clear correlation with the local polarization direction of the laser radiation.

From a theoretical point of view, a controversial debate has emerged during the last decades, whether LIPSS originate from electromagnetic effects (seeded already during the laser irradiation) – or whether they emerge from matter-reorganization processes (distinctly after the laser irradiation) (Bonse et al. 2017). From a practical point of view, however, LIPSS represent a simple and robust way for the nanostructuring of solids that allows creating a wide range of different surface functionalities featuring applications in optics, tribology, medicine, energy technologies, etc. (Florian et al. 2020 and Gräf 2020). While the currently available laser and scanner technology already allows surface processing rates at the m^2/min level, industrial applications of LIPSS are sometimes limited by the complex interplay between the nanoscale surface topography and the specific surface chemistry. This typically manifests in difficulties to control the processing of LIPSS and in limitations to ensure the long-term stability of the created surface functions.

This presentation reviews the currently existent theories of LIPSS (Bonse & Gräf 2020). A focus is laid on the historic development of the fundamental ideas behind the LIPSS, their corresponding mathematical descriptions and numerical implementations, along with a comparison and critical assessment of the different approaches. Moreover, some unsolved scientific problems related to LIPSS are identified and the pending technological limitations are discussed (Bonse & Gräf 2021). Hereby, it is intended to stimulate further research and developments in the field of LIPSS for overcoming these limitations and for supporting the transfer of the LIPSS technology into industry (Bonse 2020 and Bonse & Gräf 2021).

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