

## **From Fundamentals to Future Applications:**

Advances in Laser Surface Functionalization and Biomimetics

*Jörg Schille, Stefan Mauersberger, Andreas Gruner, Lutz Schneider,  
Kristian Kujawa, Udo Löschner*

*Laserinstitut Hochschule Mittweida, Technikumplatz 17, 09648 Mittweida*

Ultrashort pulse lasers (USPL) feature excellent beam performances and process flexibility, enabling highly efficient, high-precision material processing across a wide range of applications. Beyond micro structuring and machining, USPL-based technologies have emerged as powerful tools for tailoring surface topography and physicochemical properties, thereby enabling advanced surface functionalization and scalable microfabrication. This overview presentation summarizes recent progress in high-power USPL systems toward kW-class average power levels and discusses novel approaches for ultrafast and large-area processing. Central aspects include high-throughput scanning technologies, including galvanometer and polygon scanners, as well as spatial beam shaping strategies employing direct laser interference patterning (DLIP), spatial light modulators (SLM), and diffractive optical elements (DOE). The influence of key laser parameters on ablation efficiency and material removal rates is analyzed, providing insight into optimized high-rate machining strategies. Under optimized conditions, material removal rates of several  $\text{mm}^3/\text{s}$  and large-area processing rates beyond  $\text{m}^2/\text{min}$  can be achieved.

The second part of the presentation highlights laser surface texturing as an enabling technology for advanced surface engineering and sustainable manufacturing. Biomimetic approaches inspired by natural surface functionalities demonstrate the industrial potential of laser-induced micro- and nanostructures. Riblet surface textures are presented as a promising strategy for drag reduction and energy savings in fluid machinery applications. In addition, laser-generated microscopic textures are utilized for the fabrication of hydrophobic and self-cleaning polymer surfaces through replication and injection molding processes. By combining high-throughput laser processing with scalable replication technologies, this presentation outlines a pathway toward the industrial implementation of functionalized surfaces for sustainable mass production.