Laser-based 3D printing of micro-optics with high fidelity

Gordon Zyla[1*], Dimitra Ladika[1], Vasileia Melissinaki[1], Michalis Stavrous[1], Jan Marx[2], Ivan Kassamakov[3], and Maria Farsari[1]

[1] Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas, Heraklion, Greece

[2] Applied Laser Technologies, Ruhr University Bochum, Bochum, Germany

[3] Electronics Research Laboratory, Department of Physics, University of Helsinki, Helsinki, Finland

*Corresponding author email: zyla@iesl.forth.gr

Laser-based 3D printing through multi-photon lithography (MPL) is a highly innovative and rapidly evolving approach, holding significant promise as a future manufacturing technique for fabricating high-resolution structures, specifically in the field of micro-optics [1]. Traditionally, MPL operates on a principle that involves the use of tightly focused ultrafast laser radiation to create a 'voxel' (volume pixel) within a photosensitive material [2, 3], where the voxel size is directly proportional to the square of the laser intensity. Consequently, employing rapid laser amplitude modulation can adjust the voxel size locally throughout the printing process. This adjustment allows for a significant improvement in structural fidelity, especially for curved surfaces, and also has a dramatic impact on fabrication time.

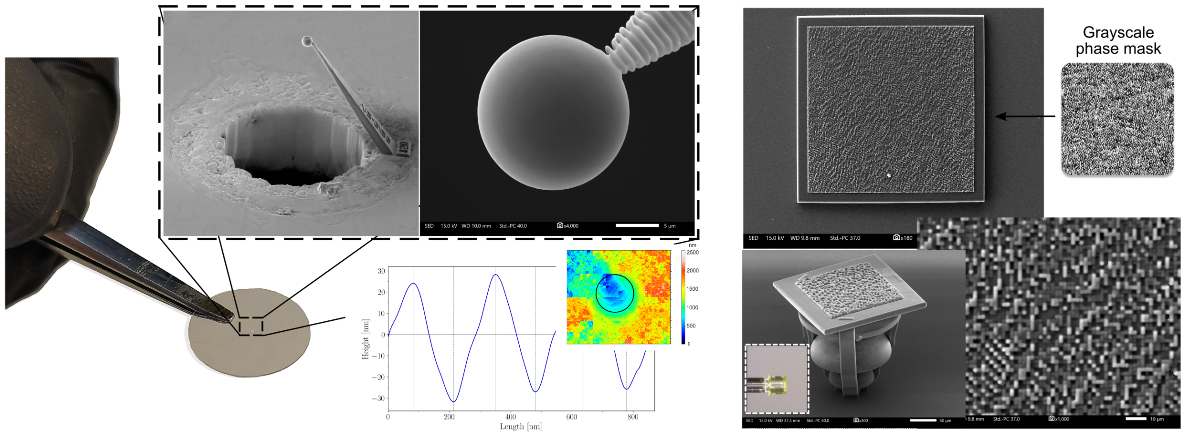

Figure 1: Micro-optics printed by advanced MPL

This work demonstrates the effectiveness of this advanced MPL strategy (see Figure 1). These technique facilitate the high-fidelity printing of spherical structures, producing micro-spheres that can enhance the lateral resolution of optical microscopes beyond the limits of conventional optics. Furthermore, advanced MPL enables the efficient fabrication of arbitrary multi-level diffractive optical elements (DOEs) and micro-sized beam expanders, whereas both can also be fabricated on challenging surfaces, such as the end-face of a single-mode optical fiber.

Acknowledgements:
This work was supported by the Marie Skłodowska-Curie Actions, under Grant Agreement No. 101059253, as part of the European Union's Horizon Europe research and innovation program.

References:
[1] H. Wang et al., Two-photon polymerization lithography for optics and photonics: Fundamentals, materials, technologies, and applications. Adv. Funct. Mater., 33, 2214211, 2023.
[2] H.-B. Sun et al., Two-photon laser precision microfabrication and its applications to micro-nano devices and systems. J. Light. Technol., 21, 624–633, 2003.
[3] E. Skliutas et al., X-photon laser direct write 3D nanolithography. Virtual Phys. Prototyp., 18, e2228324, 2023.