

3D-PRINTED DIFFRACTIVE OPTICAL ELEMENTS USING GRAYSCALE MULTIPHOTON PRINTING

Paulius Semenauskas¹, Mangirdas Malinauskas¹, Maria Farsari², Gordon Zyla¹

¹Vilnius University, Physics Faculty, Laser Research Center, Lithuania

²Foundation for Research and Technology-Hellas, Institute of Electronic Structure and Laser, Greece
gordon.zyla@ff.vu.lt

Multiphoton printing (MPP) is a maskless, high-resolution 3D printing technique that exploits nonlinear light-matter interactions to induce localized polymerization in photosensitive materials, resulting in an ellipsoidal volume pixel known as a voxel [1]. Owing to its nonlinear nature, MPP allows dynamic modulation of the printing intensity, an approach commonly referred to as grayscale MPP, enabling precise control over voxel dimensions and fabricated geometry and particularly relevant for optical applications that require high structural fidelity [2].

Here, grayscale MPP was used to fabricate multilevel pixelated diffractive optical elements (DOEs) that manipulate the phase of transmitted light. The DOEs were designed from digital grayscale phase masks generated using computer-generated holography methods [3] to produce target far-field intensity distributions. During fabrication, each grayscale pixel was translated into a discrete height level by adjusting the local laser exposure dose, resulting in quasi-2.5D surface relief profiles. The fabricated structures achieved a minimum lateral pixel size of $2 \times 2 \mu\text{m}^2$ and comprised eight discrete height levels with a step height of approximately 80 nm. Surface topography and fabrication quality were characterized using optical profilometry and scanning electron microscopy, respectively (see Fig. 1, top). Optical characterization confirmed that the printed DOEs generate the intended far-field intensity distributions (see Fig. 1, bottom).

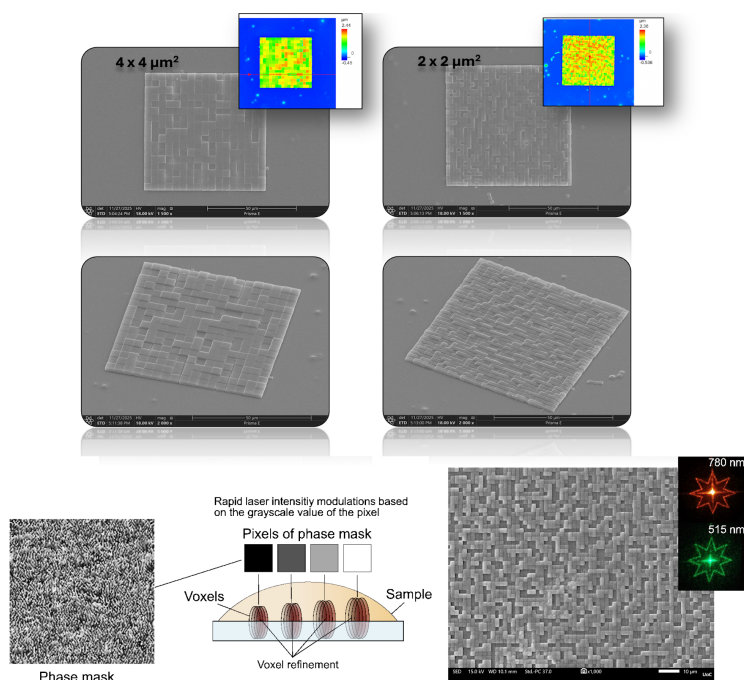


Fig. 1. Examples of multilevel pixelated structures and DOE printed by grayscale MPP

These results demonstrate that maskless grayscale MPP provides a flexible and cost-effective alternative to conventional lithographic techniques for the rapid fabrication of custom-designed DOEs, with potential applications in optical microscopy, laser beam shaping, and integrated optical systems [4].

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- [1] G. Zyla and M. Farsari, "Frontiers of Laser-Based 3D Printing: A perspective on Multi-Photon Lithography," *Laser & Photonics Review*, vol. 18, no. 7, Mar. 2024, doi: 10.1002/lpor.202301312.
- [2] G. Zyla et al., "3D micro-devices for enhancing the lateral resolution in optical microscopy," *Light Advanced Manufacturing*, vol. 5, no. 2, p. 1, Jan. 2024, doi: 10.37188/lam.2024.019.
- [3] Gerchberg, R. W. & Saxton, W. O., "A practical algorithm for the determination of phase from image and diffraction plane pictures," *Optik* 35, 237-246, 1972.
- [4] S. N. Khonina, N. L. Kazanskiy, and M. A. Butt, "Exploring Diffractive Optical Elements and Their Potential in Free Space Optics and imaging- A Comprehensive Review," *Laser & Photonics Review*, vol. 18, no. 12, May 2024, doi: 10.1002/lpor.202400377.