Massively parallel multiphoton photoplotting: rationale, techniques and implementation obstacles

K. Heggarty, L. Perez Covarrubias, A. Khaldi,
IMT Atlantique, Departement Optique, Technopole Brest-Iroise, 29238 Brest, France

Abstract:

Multiphoton (MPP) – nano/microfabrication is now a mature technology with commercial systems now available from a number of manufacturers (e.g. Nanoscribe, Multiphoton Optics, Microlight … The technique’s unrivalled combination of resolution (~10nn) and flexibility (full 3D) has resulted in the use of these systems as a tool by numerous industrial and academic R&D teams across the world for several years: see, for example [1].

However the remaining main practical drawback or weakness of the technique are the very long write times for high resolution structures with areas/volumes greater than $1mm^3$ (write times up several hours or days). This has greatly restricted the application of these techniques in the fabrication of large dimension (>cm) structures such as photonic surfaces, particularly in a production environment.

High repetition rate lasers and high speed galvo scanning have enabled plot rates to increase but the fundamental limitation results from the use of a single write beam. A similar problem in conventional “single-photon” laser writers has largely been solved through the use of massive parallelization: dividing a laser beam into up to millions of independent beams [2][3].

Some attempts have been made to apply these parallelization techniques to MPP photoplotting mainly in academic laboratories [4]. They generally use either fixed microoptical structures – such as microlens arrays in an imaging configuration or diffractive optical elements (DOEs) to gereate an array of write spots – or spatial light modulators (SLM) to generate a real-time reconfigurable array of light beams in either a Fourier domain configureation (phase-modulation SLM) or an imaging configuration (amplitude modulation SLM).

We will review these techniques and different approaches, highlighting their advantages and drawbacks and the specific difficulties involved in applying each of these techniques to MPP photoplotting. In particular, we will present the knowledge gained and recent results in our consortium has obtained in the EU H2020 Phenomenon project which aims specifically to study and implement massively parallel MPP photoplotting based on these approaches.

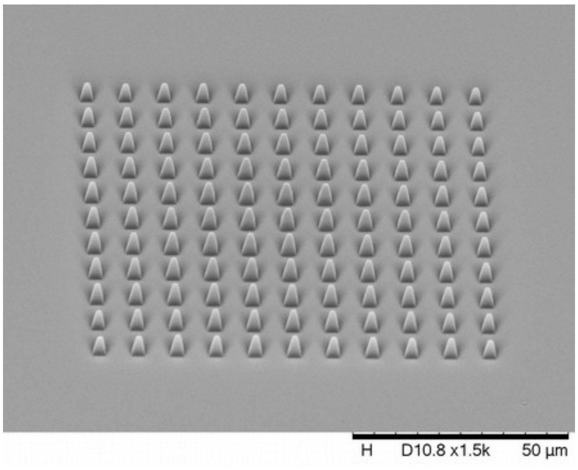

Figure 1. Array of pyramids obtained by parallel MPP with a DOE generated 11x11 array of DOE write beams in the Phenomenon project by partner Multiphoton Optics GmbH.

References:

1. T.Baldacchini, “3D microfabrication using two-photon polymerisation”, Elsevier 2016.
2. M. Kessels et al., “Versatile stepper based maskless microlithography using a liquid crystal display for direct-write of binary and multi-level microstructures”, Journal of Micro/Nanolithography, MEMS, and MOEMS (JM3), July 2007

3. H. Martinsson et al, "Current status of optical maskless lithography," Journal of Micro/Nanolithography, MEMS, and MOEMS 4(1), 011003 (1 January 2005).
4. S. Gittard et al, "Fabrication of microscale medical devices by two-photon polymerization with multiple foci via a spatial light modulator," Biomed. Opt. Express 2, 3167-3178 (2011)

Acknowledgements

The Phenomenon project received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No.780278.