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Fabrication strategies with fixed diffractive optical elements for high speed two-photon polymerization

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Abstract

The benefits of Two-Photon Polymerization (TPP) are well known for the fabrication of 3D structures with micron and even submicron sizes However the fabrication time of these structures is still far from being competitive with other techniques. In this work, the use of fixed Diffractive Optical Elements (DOEs) is presented as valid approach to boost the fabrication speed of TPP. In this way, the fabrication strategy for different 2.5D and 3D microstructures, taking advantage of the use of DOEs with different optical configurations, is presented and discussed. The results of this study suggest that the fabrication speed can be increased up to 20 times through the correct combination of DOE and path planning, without the need of an excessive average power.

Keywords: Two-Photon Polymerization;

1. Introduction

Two Photon Polymerization (TPP) is a very well know 3D fabrication technique that has been already used for the production of different microstructures in a wide range of applications (Serbin et al., 2003; Waheed et al., 2016) as for example the fabrication of 3D scaffolds for applications in tissue engineering (Ovsianikov et al., 2011). However, one of its main disadvantages is the low fabrication speed, which makes it not very suitable for the fabrication of large pieces or large batches. Fortunately, current development in optics and materials (Arnoux et al., 2020, Desponds et al., 2020, Pérez-Covarrubias et al., 2020, Hilbert el al., 2020) have demonstrated that fabrication speed can be boosted up by tailoring the photocurable materials properties and using parallelization optics. In this way, parallelization optics maintains the execellent properties of TPP

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while promoting fabrication speeds orders of magnitude faster than conventional TPP, specially for the fabrication of repetitive patterns which are of great interest for some photonic applications like metallenses (She et al., 2018).

In this work, we report on the different approaches for the optimization of the fabrication speed of TPP by choosing the adequate fixed parallelization optics, in this case Diffractive Optical Elements (DOEs), and scanning strategy.

2. Discussion

The use of DOEs is mostly indicated for the fabrication of 3D structures with a certain symmetry or pattern, like for example the fabrication of parallel lines, squared meshes or cylindrical and spherical microstructures. Additionally, the use of DOEs does not need of additional optics with respect single beam TPP, since we only need to introduce the DOE in the laser beam path, just before the microscope objective, as indicated in Fig. 1.

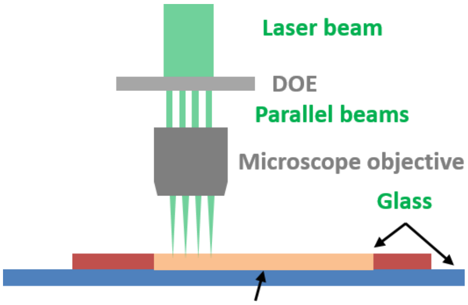

Fig. 1. Parallelization with DOEs

The DOEs can be designed to obtain the desired pattern inside the resin, according to the shape of the microstructure that we want to fabricate, for example the DOE on the left image of Fig. 2 generates 51x51 parallel beams allowing the fabrication of 2601 parallel structures by just scanning the laser beam inside the resin with the path needed for the fabrication of one single structure, but fabricating 2601 structures at the same fabrication time. On the other hand, by scanning a modulated light intensity distribution in three parallel lines, like the one on the right image of Fig. 2, through the direction perpendicular to the parallel lines, the fabrication of 1D prisms with different heights and widths could be achieved. In this way, by optimizing the design of the DOE and the fabrication strategy, the fabrication speed of TPP can be boosted up by several orders of magnitude, depending on the design of the microstructure to be fabricated.

Fig. 2. Examples of DOEs with (left) a squared array of dots and (right) a modulated light intensity distribution in three parallel lines

3. Conclusions

The results of this study suggest that the fabrication speed of TPP can be increased up by several orders of magnitude through the correct combination of fixed DOE for beam parallelization and path planning, without the need of an excessive average power.

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