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Abstract

Measurement setups and strategies for enhanced 3D printing of mesoscale optics for industrial applications

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Two-photon polymerization (2PP) lithography is an additive manufacturing technique which is capable of printing structures down to sub-micrometer resolution. Therefore, it is suitable for demanding optical applications that use complex design geometries while adhering to a high shape accuracy. The benchmark for surface roughness typically is 10 nm RMS which is sufficient for imaging applications. However, the printing of mesoscale optics with outer dimensions in the range of 1 mm to 10 mm leads to certain difficulties. The printing time may extend up to several hours which limits the use of 2PP lithography in high-throughput industries. Also, structural size and functionality are limited due to the working distance of the illumination optics or stitching artifacts imposed by the associated field of view. Consequently, existing literature on 2PP lithography primarily focuses on microstructures and sub-millimeter sized optics [1].

In this work, we introduce innovative concepts addressing the challenges associated with the lithographic manufacturing of mesoscale optics. The key strategy is to print the outer shell of optical components with inorganic-organic hybrid polymers (ORMOCER®s, [2]) followed by 1PP polymerization of the enclosed volume to reduce printing time. Stitching artifacts may be reduced in combination with the Infinite Field-of-View (IFoV) technology comprised in the *MPO 100* (Heidelberg Instruments Mikrotechnik GmbH, Heidelberg, Germany) 2PP lithography system.

In addition to the setup presented in [3] which operates with visible light and measures transmitted wavefronts, we present a method to assess the surface shape quality of printed optics using UV-light. We developed an improved setup to measure the surface figure in reflection while simultaneously suppressing unwanted reflections from subsequent surfaces by using absorption inside the material. Consequently, the use of this method heavily depends on the polymer's unique absorption spectrum. Secondly, we describe a long-term experiment with high-intensity blue light to measure the polymer's attenuation coefficient over an extended time interval as an indicator of optical stability. As long as polymer degradation can be controlled, this could help miniaturizing the design of complex beam shaping optics for high energy laser diodes.

Author's statement

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