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# Comparative Performance Analysis of Multi-level Diffractive Lens and Lens Fabricated by Grayscale Lithography and Soft-imprinting

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**Abstract:**
Grayscale Diffractive Optical Elements (DOEs) offer superior versatility and precision in shaping light fields compared to multi-level DOEs. Its continuous grayscale modulation enables finer control, leading to enhanced performance in various optical applications.


## 1. Introduction

Diffractive Optical Elements (DOEs) stand at the forefront of modern optical technology, revolutionizing diverse fields ranging from imaging systems to telecommunications. Their significance lies in their ability to precisely manipulate light, offering advantages over traditional refractive optics. DOEs enable compact, lightweight optical systems with complex functionalities, driving advancements in areas such as augmented reality, laser beam shaping, and biomedical imaging.

Today, most of the existing DOEs are fabricated using a multi-level approach; that approach involves advanced lithography to transfer the design onto a chosen substrate. Photolithography exposes the substrate to create the pattern, followed by etching or optical material deposition to achieve different depths for each level [1]. The diffraction efficiency of DOEs typically increases with the number of levels. More levels allow for finer control over the phase of diffracted light, resulting in more precise interference patterns and theoretically higher diffraction efficiency. However, Increasing the levels of diffractive optical elements (DOEs) raises fabrication complexity and costs. It also poses challenges in alignment, resolution limits, and spectral bandwidth trade-offs. All these limitations make the diffraction efficiency significantly lower than the expected value [2].

To overcome fabrication challenges associated with multi-level DOE, grayscale lithography offers a streamlined solution to challenges in fabricating multi-level diffractive optical elements (DOEs). A single exposure reduces complexity and costs, enhances resolution, removes alignment issues, and provides flexibility in optimizing spectral bandwidth [3].

## 2. Grayscale and UV-imprint method

Grayscale lithography started evolving in the mid-20th century and made big advancements in the last decade. Despite that, this method is still not widely used for DOEs fabrication, especially because of its complexity, cost, and fabrication time. Fortunately, the new generation of mask writers became available and started integrating grayscale capabilities with conventional write modes.

In this work, we will demonstrate that using a standard mask writer with grayscale capabilities (Heidelberg DWL66+ instrument) could make the fabrication of grayscale DOEs easier and faster than multilevel DOEs because it requires only two lithography steps. The first step is the transfer of the pattern on the photoresist by using the mask writer, and the second step is the transfer of the pattern from the resist to a UV resin by soft-imprint or UV molding for permanent application. In this work, We will do a comparative analysis of the performance of a 16-level diffractive Fresnel lens and a diffractive lens fabricated by grayscale lithography and UV-imprint. Fig. 1 show the two designs that we will use for our work.

Initial fabrication results are shown in Fig. 2. The figure shows the 3D profile of a Fresnel lens fabricated by grayscale lithography on AZ4562 photoresist and then transferred on UV resin by UV-print step. The lens will have full characterization, and results will be compared with a 16-level lens fabricated by Standard $2^N$ processing (N=4 for 16-level lens) [1]. The characterization results will be presented at the conference.

The 16-level lens took five working days to fabricate in the cleanroom, compared to the grayscale lens, which took only one working day between the mask writer and the transfer of the pattern from resist to UV resin. This

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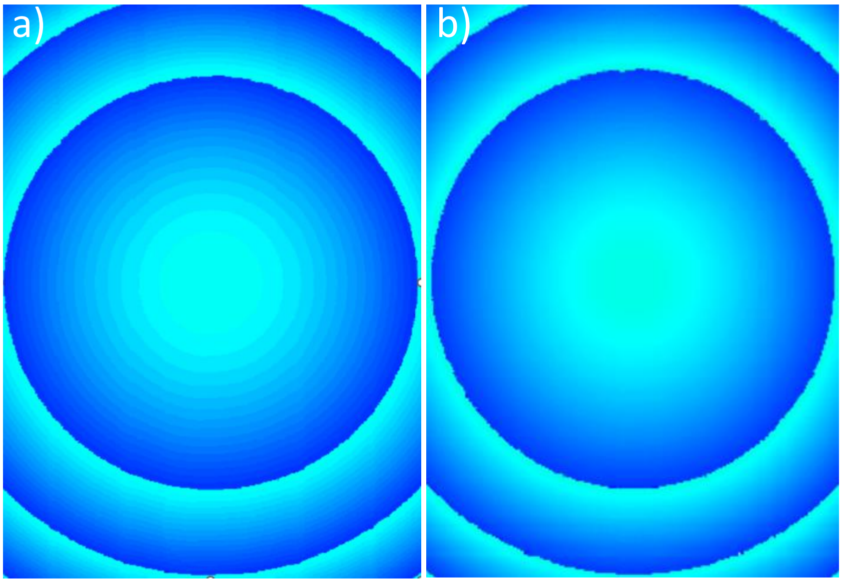


Fig. 1. Phase profile of the designed lenses. a)16 gray levels diffractive lens, b) 255 gray levels lens.

demonstrates that the cost and complexity of grayscale lithography for low-volume or research applications are in favor of grayscale lithography compared to traditional lithography techniques.

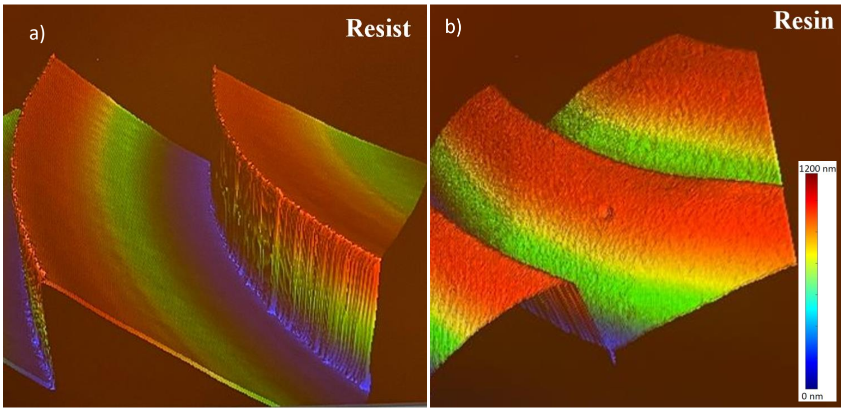


Fig. 2. 3D profile measurement of the fabricated 255 levels grayscale lens ($f = 100mm$) on Zygo profilometer (NewView 7300). a) The grayscale Fresnel lens on AZ4562 photoresist, and b)the lens transferred to UV resin by UV imprint

## References


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