# Optimization of the Built-in Lens Mask for Three-Dimensional Photo Lithography

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The built-in lens mask (BILM) was shown to be able to form a three-dimensional image in a single exposure by using its multiple focus function. The built-in lens mask consists of a masking part and a transmission part with different phases, which regenerates a complex wave plane that is formed in three dimensions[1]. The design of the mask is based on a theory based on Fourier transform optics, but the three-dimensional structure causes mutual interference. Therefore, a mask designer had to modify the mask layout one after another.

In this study, we propose an automatic mask design system based on novel feedback procedures for three-dimensional photo lithography.

The 3D structure is imaged by superimposing multiple so called `seed' as element structure, which is theoretically derived based on Fourier optics. The BILM emulate the wave plane complex amplitude to be focused in 3D space and has capability to have multiple focal at arbitrary depths in space for the seed patterns which create 3D structure. When creating the actual mask pattern, the transmittance and phase shifting amount should be binarized and some conflictions between seed patterns happed due to optical interferences, the 3D images sometimes broken down. To avoid such confliction, the seed is designed by try and error.

In order to create 3D imaging close to the ideal target shape, the simulated optical images are compared with the target profile shape, and an error is feed backed toward new seed patterns until the error to be superseded. This optimization flowchart shows Figure 1. The seed pattern without optimization is made based on the target shape.

Figure 2 demonstrates 3D images image and BILM layout on regular hexagonal spiral structure by computational lithography. When this structure is projected onto the xy-plane, the regular hexagonal has a side length of 24 μm, and When the helix structure goes around, it advances 36 μm in the z direction. The spiral structure goes around twice. The distance between the mask surface and the uppermost part of this structure is 60 μm. By optimization of the BILM mask, the optical image becomes smooth and unity. Other novel 3D structures will be demonstrated.

We will present experimental results for 3-D lithography using this system.

[1] T. Tanaka, et al., J. Vac. Sci. Technol. B-35, 06G308 (2017).

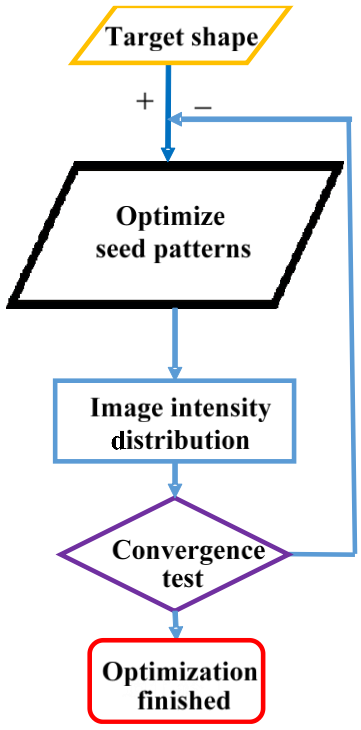
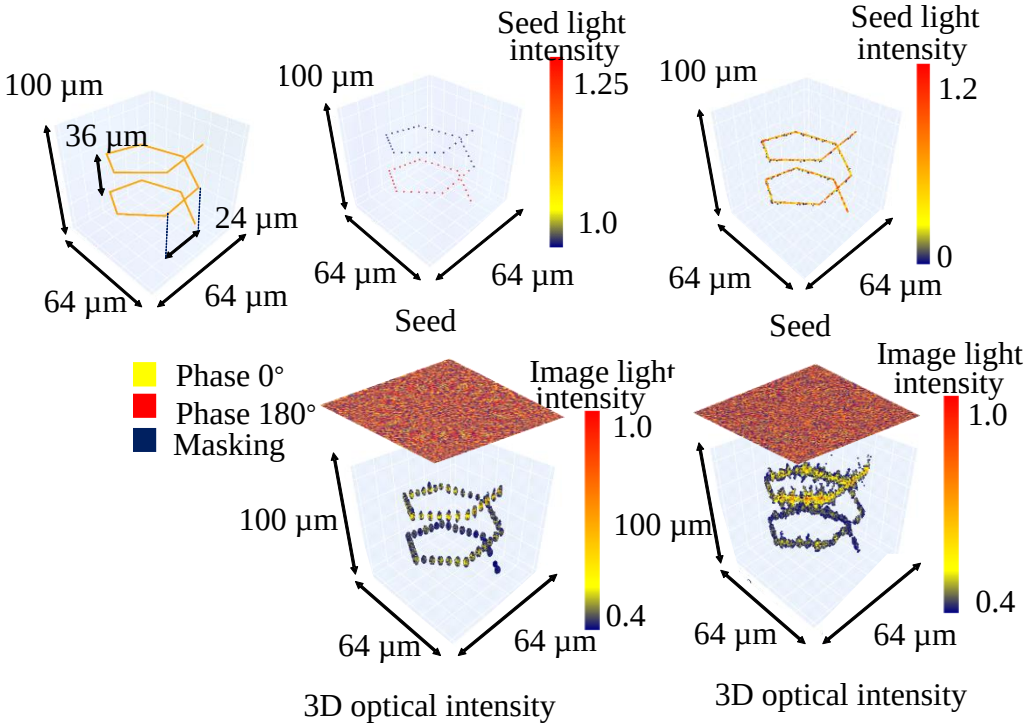



Figure 1. Optimization flowchart




a) Target profile b) without optimization c) Optimized BILM

Figure 2. Seed pattern (Upper), BILM pattern (Middle) and 3D images(lower) on regular hexagonal spiral structure (λ=365nm)