Towards Roll-to-Roll Manufacturing of Holographic Nanopatterning by Leveraging Laser Diode Arrays Contained within an UVT Acrylic Roller

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Roll-to-roll nanomanufacturing in 3D has historically been challenging to achieve due to the difficulties in multilayer alignment. With developments in multi-material holographic lithography and interference lithography, the opportunity arises to overcome these challenges by eliminating the need for multilayer alignment and implement three-dimensional nanoscale manufacturing in a single exposure. Of course, redesigning novel lithography methods for use in a moving, flexible substrate introduce their own challenges. This paper demonstrates a scalable, high speed, design for dual wavelength near field illumination is encapsulated inside of our pacer roller.

The architecture shown in the schematic in Fig. 1 (a) demonstrates the multi-wavelength optomechanical architecture that allows control of the speed and tension of both the mask web and substrate web. This allows for deformation-free contact between the mask and the substrate to enable the best lithography conditions.

Approaching the challenge of creating a consistent exposure intensity across the entire web within the spatial constraints of a roller necessitated the use of a laser diode array over other optical beam expanding methods. An array of 19 laser diodes (LDs) of each wavelength allows the light source to reach the collimation, dosage level, and dosage homogeneity required for acceptable exposure conditions. The data shown in Fig. 2 (a) demonstrates optical simulation methods being taken to optimize a roll-to-roll holographic lithography prototype and demonstrate the exposure across the web.

Curing three dimensional structures into a thick photoresist layer also requires demonstrating that the proper collimation gives repeatable spatial interference to prevent pattern loss deeper into the photoresist. By leveraging a Talbot imaging algorithm, and couple wave simulation, it is possible to demonstrate the success that LDs are able to create the desired structures, as shown in Fig. 2 (b)

A final volumetric model of the three-dimensional volumetric intensity profile produced by the mask is then generated using a finite-difference time-domain (FDTD) simulation Fig 2 (c). The combination of these simulations supports and informs the design decisions behind the prototyping of this roll-to-roll system and sets the foundation for validating future experimental results.

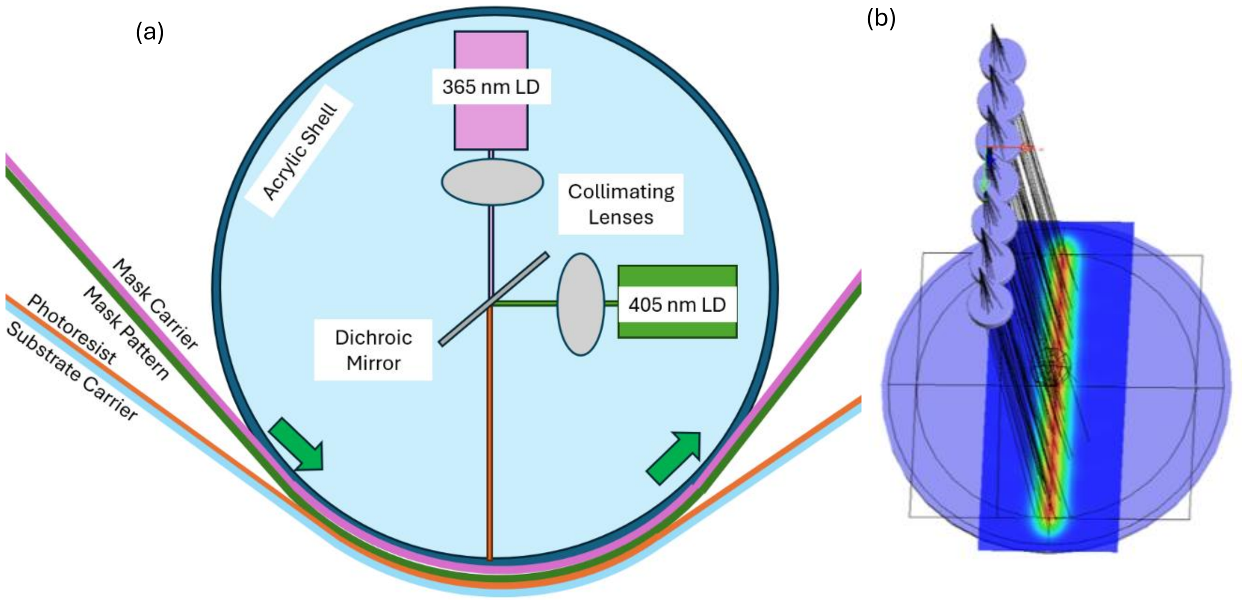

Figure 1: (a) A basic schematic of the optical architecture within the roll-to-roll and web system. The UV Acrylic shell rotates using air bearings and the optics are mounted using a hollowed dead shaft configuration. (b) LightTools ray tracing simulation demonstrates the some of the laser diodes. array and the overlap.

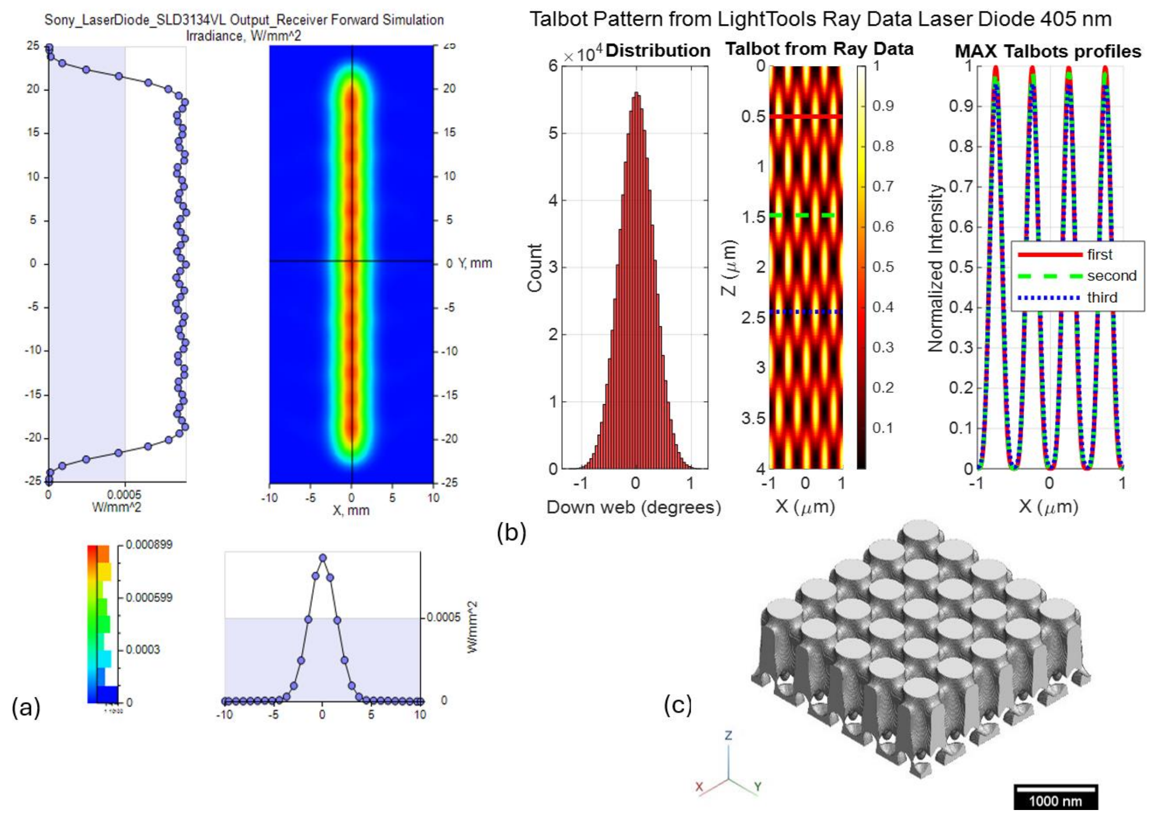

Figure 2: (a) Example irradiance band on the mask. (b) Using couple simulation shows acceptable Talbot contrast. (c) Finite-difference time-domain (FDTD) simulation of a 5 by 5 mask element.