Design and Fabrication of broadband diffractive optics

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Diffractive optics offer advantages over conventional refractive optics due to their thin planar geometries and significantly reduced weight. However, conventional diffractive optics suffer from strong chromatic aberrations.[1] Therefore, these are designed to operate over narrow bandwidths. We recently applied the principles of computer-generated holography with numerical nonlinear optimization to design broadband diffractive optics.[2-4] Such optics would have important applications in lightweight digital cameras, solid-state lighting, solar concentrators, etc. The simulated optical efficiencies of such optics, which we call polychromats can be very high as illustrated by an example in Fig. 1.

In order to achieve high optical efficiencies, the polychromats require multi-level lithography. We recently developed a grayscale lithography process using an optical pattern generator to fabricate polychromats with 4 or more levels. An example of such an optic is shown in Fig. 2. The multiple levels of heights are achieved via careful dose calibration of the tool. In other words, dose modulation was used to generate multiple discrete levels within a ~1μm thick photoresist layer. The dose modulation also causes undesirable variations in the feature size. We corrected for these errors using an empirically measured linewidth bias.

In this presentation, we will describe the design approach, fabrication methodologies and optical measurements from these unique optical elements.

References:

[1] S. Noach, A. Lewis, Y. Arieli, and N. Eisenberg, "Integrated diffractive and refractive elements for spectrum shaping," *Appl. Opt.* 35, 3635–3639 (1996).
[2] D. E. Goldberg, "Genetic Algorithms in Search, Optimization, and Machine Learning," Addison-Wesley (1989).
[3] J. A. Dominguez-Caballero, S. Takahashi and G. Barbastathis, "Design and sensitivity analysus of Fresnel domain computer-generated holograms," *Int. J. Nanomanufacturing (in press)*.
[4] R. Menon, *et. al*, "Design of diffractive lenses that generate optical nulls without phase singularities," *J. Opt. Soc. Am. A*, 26(2), 297 (2009).

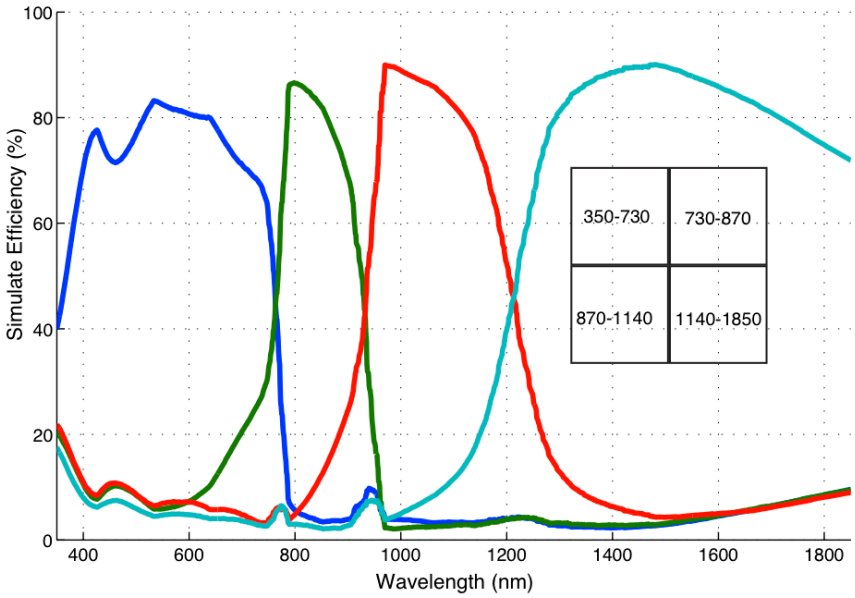

Figure 1: *Simulated optical efficiency as a function of wavelength for a polychromat, which separates the solar spectrum into 4 spatially separate quadrants as illustrated in the inset diagram. Efficiencies in excess of 75% are seen over the entire spectrum.*

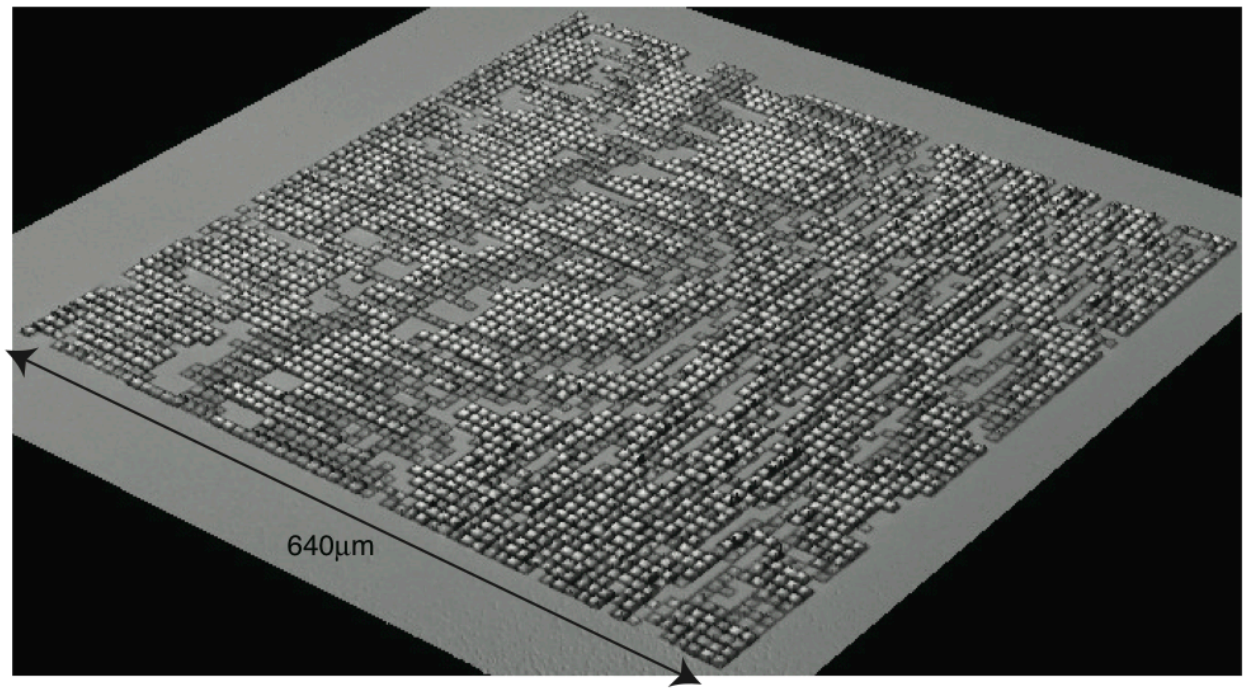

Figure 2: *Optical profiler image of a polychromat with 4 gray-levels. The substrate is a glass blank and the patterns are in Shipley 1813 photoresist. Four different colors indicate the 4 distinct height levels.*