High-Efficiency Freeform Diffraction Grating Structures for Parallel Processing

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Ultrafast lasers utilised for microprocessing tend to have more average power than is optimal for a single processing location. To further increase throughput, it is common practice to use a beam splitting diffractive optical element (DOE) to distribute the power among multiple processing beams in both 1D and 2D arrays for parallel processing.

Commercially available DOE solutions are commonly manufactured using lithography techniques which have design restrictions, namely the trade-off between diffraction efficiency and manufacturing cost. Binary lithography can provide low-cost optics with limited efficiency, while multi-level lithography can increase efficiency towards theoretical limits. However, this requires multiple lithography exposures, which can be comparatively expensive in both manufacturing time and tooling. For odd numbers of spots, optimal phase solutions can be formulated from the combination of harmonic sinusoids of a fundamental grating period [1]. Freeform laser processing techniques allow for manufacture of these smoothly varying surfaces with high diffraction efficiency at no additional processing cost.

We present new capabilities in laser processing of beam splitting DOE in linear 1D and 2D arrays, as well as a hexagonal array. Surface conformity and simulated performance achieved is presented and compared to observed results in processing trials. Scope for the available design space for this manufacturing method for DOE are discussed along with other potential applications.

[1] Louis A. Romero and Fred M. Dickey (2010) Progress in Optics Volume 54 (Elsevier), Chapter 6 - The Mathematical Theory of Laser Beam-Splitting Gratings