Full Spectrum Big Data Analysis for Dynamic Freeform Optics Manufacturing

Dae Wook Kim[1,#], Geon-Hee Kim[2], Xiangyu Guo[3], Logan Graves[1], Isaac Trumper[1], Yong Shu[4], Maham Aftab[5], Heejoo Choi[1]

1 College of Optical Sciences, The University of Arizona, USA
2 Division of Scientific Instrumentation, Korea Basic Science Institute, Republic of Korea
3 Department of Mechanical Engineering, Texas A&M University, USA
4 Aviation Maintenance NCO Academy, Air Force Engineering University, China
5 James C. Wyant College of Optical Sciences, The University of Arizona, USA
Corresponding Author / E-mail: letter2dwk@hotmail.com

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Future freeform optical systems, astronomical telescopes, advanced instruments, and high contrast camera systems are enabling exciting new developments in various academic and industrial areas. These precision optical systems are often fabricated using a computer controlled optical surfacing process. In order to guide the manufacturing process, a series of metrology concepts and data handling processes have been investigated, published, and summarized in this abstract. As a manufacturing solution, a freeform post-processing technique was developed to maintain the large-scale freeform shape while improving small-scale surface quality. The full aperture tool can avoid subaperture effects, while the pseudo-random orbiting stroke of the tool prevents directionality in the final surface profiles. To measure freeform optics, an instantaneous phase shifting deflectometry has enabled measurements of a time varying deformable mirror. The instantaneous method is based on multiplexing fringe patterns with color and decomposing them using Fourier techniques. A unique error correction based on the quasi-static common-configuration measurement is leveraged to achieve accuracy similar to interferometry. A model-free reconstruction methodology addresses the uncertainty in the Unit Under Test (UUT) model shape. The software provided improved surface reconstruction accuracy without the need of a UUT model using an iterative process shown in Figure 1. For the big data analysis, a polynomial set based on the gradients of 2-dimensional Chebyshev polynomials, called G polynomials can reconstruct surfaces by fitting raw slope data. This fit provides up-to hundreds of thousands of modes, which is important to represent high-resolution data and freeform surfaces. It is computationally efficient and allows accurate reconstruction when blockers or markers are present on the optics. In order to guide a real-time optical system alignment, SMOTS has been developed utilizing the localized sheared images. The sheared pattern images are analyzed in the Fourier domain, and the calculation results provide 0.8 μrad angular accuracy in real-time monitoring. This method could measure many segmented mirrors and the computational time is about 0.07 seconds using a conventional PC. Accurate, fast, and efficient numerical data analysis solutions have been developed. A suite of testing and fabrication approaches have been applied to various freeform optics manufacturing projects. These full spectrum metrology systems and intelligence-guided fabrication technologies produce a comprehensive big data set both in spatial and temporal domains that needs to be efficiently and accurately processed and analyzed. The systematically analyzed holistic process-control information reshapes the next generation optics manufacturing technology utilizing the full spectrum metrology resources.

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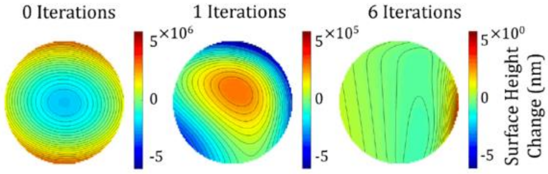

Fig. 1 Model-free deflectometry surface shape map change between 0 (left), 1 (middle), and 6 (right) iterations. The most significant reconstructed surface shape change occurs in early iterations. This result clearly demonstrates the importance of efficient and accurate data processing methodology for the freeform optics metrology application. The black lines show the reconstructed freeform surface height contours