Title : Dynamic Interferometry for Surface Form and Finish Metrology

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Abstract

Significant advances in the field of "dynamic interferometry" have been implemented in recent years enabling cost-effective, vibration-insensitive interferometry systems for quality control measurements in a variety of applications. One recent dynamic interferometry technique utilizes polarization to acquire single camera, single exposure phase shift measurements.

Essential to this technique was the development of a new class of interferometer phase sensor based on a CCD pixel-level phase-shifting method. This device is discussed here with theoretical and experimental results. Analyses of component errors and instrument functionality are presented. The majority of error sources cause relatively small magnitude errors in measurement on the order of 0.5nm or less. . These errors are largely mitigated via high rate data acquisition and consequent data averaging. Additional noise reduction techniques for these coherent optical systems will also be presented.

Further, the spatial frequency response of the pixelated phase mask sensor has been investigated both theoretically and experimentally. Using the small phase step approximation, it is shown that the instrument transfer function can be approximated as the product of the system optical transfer function and the spatial carrier processing filter transfer function. Optimum performance is achieved when the bandwidth of the optical imaging system is configured so that the limiting factor is the detector pixel width. Measurement results will be presented for a commercial Fizeau interferometer that agree very well with the theory, and demonstrate detector limited performance. The spatial resolution of the calculated phase map is processing algorithm dependent; however, both the 2x2 and 3x3 convolution algorithms result in a frequency response that is significantly more than what would be obtained by a simple parsing of the image. A 1k x 1k sensor has a spatial frequency response that is approximately equal to the detector limited resolution of a 700 x 700 array with its frequency response extending to the full Nyquist limit of the 1k x 1k array.

Implementation of this sensor with a number of interferometer configurations for the measurement of surface form and roughness will be presented and discussed. These systems have been implemented to make vibration insensitive measurements and provide feedback for computer-controlled polishing operations, measurement of moving surfaces, to verify dimensional stability of support structures, alignment of mirror segments and optical beam trains, and to complete other critical metrology applications. Various applications and results will be presented.