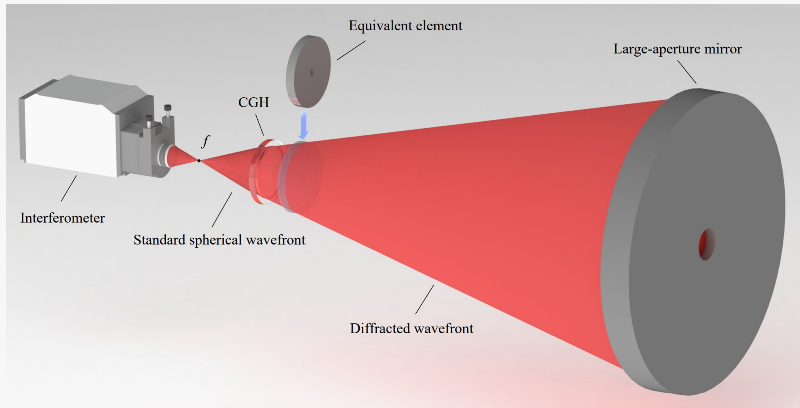
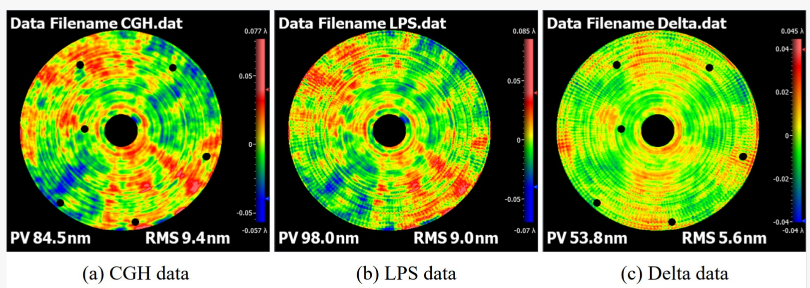
Accuracy verification methodology for CGH used for testing ultra-large aperture mirrors

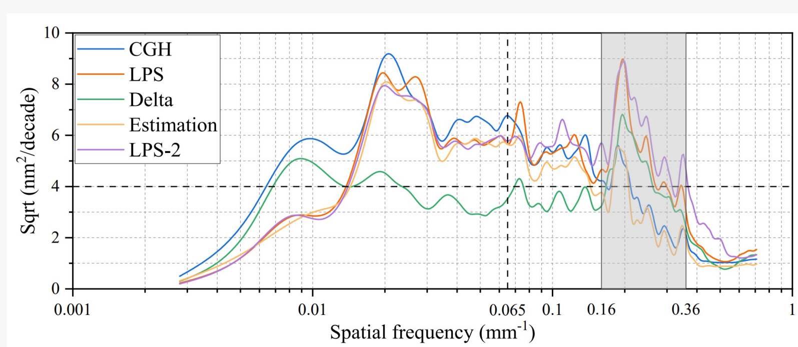
USA, September 3, 2024 /EINPresswire.com/ -- Computer-generated hologram (CGH) is a unique solution for the highly accurate testing of large-aperture aspheric mirrors, and its accuracy calibration has become one of the long-standing difficulties in this filed. Scientist in China developed an accuracy verification methodology based on an equivalent element, which transfers the aspheric wavefront reference in a comparison test. This technique will provide a feasible solution for CGH accuracy verification, ensuring high-accuracy and reliable testing of large-aperture aspheric mirrors.



A typical layout used for testing large-aperture mirrors with a CGH as the null lens. The surface shape of the equivalent element is obtained by scaling a large-aperture mirror along the optical axis.



Error maps obtained using the (a) CGH and (b) LUPHOScan. (c) Their pointwise deviation map.



RMSD curves of the error maps.

In the ultra-precision machining of optical components, the checking tools are specially used to control their surface shape accuracy. As the ultra-precision core component of telescope systems, the surface shape accuracy of large-aperture aspheric mirrors often requires to meet nanometer level, which is a severe challenge for the accuracy verification of checking tools. Interferometry with computer-generated hologram (CGH) generates the designed wavefront reference to test aspheric and freeform surfaces. Due to the lack of comparison test methods, its accuracy calibration has become one of the long-standing difficulties.

In a new paper (doi: https://doi.org/10.37188/lam.2024.025) published in Light: Advanced Manufacturing, a team of scientists, led by Professor Xuejun Zhang from Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, China, and co-workers have developed an accuracy verification methodology for CGH used for testing large-aperture aspheric mirrors based on an equivalent element. The equivalent is functionally equivalent to the large-aperture mirror in terms of accuracy verification, but its aperture decreased by one or higher orders of magnitude. This implying that the mirror could be replaced by a non-CGH technology in a comparison test. The comparison test is a direct verification method that uses two or more methods to test the same element, and the differences in the measurement results directly reflect the reliability of the measurement accuracy. The reported method and technique will provide a feasible solution for CGH accuracy verification, ensuring high-accuracy and reliable testing of large-aperture aspheric mirrors.

The equivalent element actually transmits the wavefront reference of the large-aperture aspheric mirrors, thereby breakthrough the aperture limitation. By using aperture-limited high-precision profilometry, comparison test could be performed on large-aperture aspheric mirrors. More high-precision testing methods could also be used for comparison measurement and analysis, thereby improving the reliability of measurement accuracy. These scientists applied the verification methodology into a real CGH used for testing a 3.5 m aspheric mirror:

“We design a 281 mm equivalent element to replace the 3.5 m aspheric mirror in the comparison test. It is measured using CGH and LUPHOScan profilometers. The surface error composition and root-mean-square (RMS) density analyses are performed to find out the consistency between these two measurement results. The analysis results show that the methodology verification accuracy of the CGH was 4 nm (RMS) in the low- to mid-frequency bands, with a measured surface accuracy of approximately 10 nm (RMS).”

“This verification methodology is effective and the accuracy could reach the nanometer level. The presented technique can be used to test the real measurement accuracy of CGH used in the ultra-precision machining of optical components, especially for the large-aperture mirrors. If higher-accuracy non-CGH technology can be used, the methodology verification accuracy for CGH can be improved further” they added.

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