Instantaneous phase-shifted speckle interferometer for measurement of large optical structures

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Abstract: An instantaneous phase-shifting interferometer (PhaseCam, 4D Technology) was modified to a speckle phase-shifted interferometer. This interferometer was used to measure "diffused" objects such as a carbon fiber. Repeatability, accuracy, and dynamic range of the interferometer were measured. Different phase shifting algorithms were utilized to get rid of the high frequency speckle that modulates the low frequency fringes.

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Summary

The JWST telescope is an anastigmatic, segmented cryogenic telescope. The stability of the primary mirror is a major concern in co-phasing the telescope.

In order to co-phase the telescope, the back plane structure, which holds the mirror segments, must be stable. The error allocations for in-plane and out of plane motions (perpendicular to the surface) are maximum of 300 nm maximum, and 20 nm RMS respectively. As part of their IR&D efforts, NGST (then TRW) investigated in-plane motion of the back plane structure due to changes in the temperature. They showed the in-plane motion of the structure is within the error budget. They could not use the same metrology to measure out of plane motion because distinguishing the back plane motion from motion of the metrology at the level of 20 nm RMS was not possible. Therefore a different approach needs to be developed to measure the out of plane motion of the back plane structure, one in which there are no metrology attachments.

The back plane is a 6-meter structure constructed of carbon fiber, and is therefore a "diffused" object, an object with surface roughness larger than the wavelength of the light. For this reason classical interferometric measurements will not work. The objective is to present specific speckle interferometers that have the most potential to measure the JWST back plane structure within the required accuracy.

Instantaneous phase-shifted speckle interferometry is a method of measuring the back plane deformations that has the potential of reaching the required accuracy in presence of vibrations at cryogenic chambers.

4D Technology Corporation, in Tucson, Arizona has an instantaneous phase shifted interferometer (PhaseCam) that was modified to an instantaneous phase-shifted speckle interferometer. A piece of the back plane structure (1"x 1") carbon fiber is measured to get repeatability, dynamic range, and accuracy of this modified interferometer. In addition, a spectrophotometer is used to measure reflection of the carbon fiber material at visible range. Combining the spectrophotometery and the interferometry measurements enables us to design and fabricate an instantaneous phase-shifted speckle interferometer that can be used to measure a 3-6 meter "diffused" structure, such as primary mirror back plane in vibrational environments.