Paper ID: 51178
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IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Smart Materials and Adaptive Structures (9)

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LABORATORY DEMONSTRATION OF COHERENT COMBINATION OF SPARSE APERTURE IMAGES

Abstract

Several future imaging missions will require large space mirrors, 10-20 m in diameter. This is a challenging problem on how to build cost-effective large aperture mirrors with surface error accuracy in the range of 30 nanometer RMS. In order to achieve these performances, use of several smart structures technologies are proposed. At Naval Postgraduate school (NPS), research has been performed on 3-meter diam., 6 segments with 156 smart actuators for surface control and 3 fine and 6 coarse actuators for phasing for each segment. Another attractive approach is to use sparse aperture concept. Sparse aperture concept consists of putting several satellites in orbit with small apertures and coherently combine their images, resulting in resolution of a satellite with large aperture. Sparse aperture concept is attractive in many ways but has several technical challenges, such as having these satellites move accurately in satellite formation representing parts of a large aperture, metrology to measure errors in satellite formation in few nano- meters, and optics for coherently combine these images. Based on several feasibility studies, it has been concluded that the many of the key sparse aperture technologies are developed and demonstrated in the component level, but lacking in the system level demonstration. NPS in 2016 started project to develop a test bed to demonstrate sparse aperture concept. The test bed development is now completed and sparse aperture concept is successfully demonstrated. This paper will present experimental results of NPS Sparse Aperture Testbed. Developing testbed for sparse aperture was very challenging as the measurement of errors and correction are in few nano- meters range. We did trade-off on the selection of shape of the apertures, metrology system, and beam-combining platform for correction of formation errors. In the testbed, sparse aperture array consists of three 2-inch diameter F/20 spherical mirrors. Each mirror is connected to a separate six axis NanoMax Nano Positioning Flexure Stages developed by ThorLabs to simulate aperture motion in satellite formation. The beam-combining platform employs three 1-inch diameter flat mirror mounted on the correcting tip/tilt/piston actuated stages by physik instrumente (PI) to provide coherent beam combining capabilities in the presence of sparse aperture array errors. For metrology, the system uses nine Zygo single-axis displacement-measuring interferometers. Transformation matrix between the aperture motion measured by metrology and required motion by correcting piston and tip/tilt stages was determined. Several cases of images were tested for sparse aperture concept.