

Testing the James Webb Space Telescope Primary Mirror

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Abstract: JWST in-process optical testing and cryogenic requirement compliance certification, verification & validation was probably the most difficult metrology job of our generation in astronomical optics. But, the challenge was met: by hard work of dozens of optical metrologists; development and qualification of multiple custom test setups; and several new inventions, including 4D PhaseCam and Leica Absolute Distance Meter. This paper summarizes the metrology tools, test setups and processes used to characterize the JWST primary mirror.

Keywords: Optical Testing, Optical Metrology

Introduction

In-process optical testing and final compliance testing of the James Webb Space Telescope (JWST) Primary Mirror was probably the most difficult astronomical optics metrology job of our generation.

The JWST 6.5 m diameter primary mirror is nearly a parabola with a conic constant of -0.9967 and radius of curvature of 15.880 m at 30K. The primary mirror is divided into 18 segments with 3 different prescriptions. The primary difference between segment type is the off-axis distance (and hence the aspheric departure). The radius of curvature for all 18 segments must match to +/- 0.150 mm at 30K. JWST is diffraction limited at 2 micrometers which translates into a transmitted wavefront specification of 156 nm rms. Of that amount, 50 nm rms is allocated to the primary mirror. Each segment is allocated 22 nm rms surface error. The PMSA surface figure error is divided between three spatial frequency bands: 20 nm rms is allocated to surface errors with low and mid-spatial frequencies longer than 222 mm/cycle; 7 nm rms is allocated to spatial frequencies from 222 to 0.08 mm/cycle; and 4 nm rms is allocated to surface roughness. The primary mirror has a collecting area specification of 25 square meters at 30K. When this requirement is flowed down to the segment level, taking into account all potential obscuration losses and material shrinkage, it yields a 1.48 square meter requirement per segment which translates into a clear aperture specification of 7 mm from the physical edge.

The JWST primary mirror optical metrology was performed using the following seven guiding principles for optical testing:

1. Fully Understand the Task
2. Develop an Error Budget
3. Continuous Metrology Coverage
4. Know where you are
5. 'Test like you fly'
6. Independent Cross-Checks
7. Understand All Anomalies

All JWST primary mirror segments meet their requirements and are on schedule for a 2018 launch. The next step is system level assembly, integration and test. Ambient tests will be conducted at Goddard Space Flight Center and cryogenic system level testing will be performed in Chamber A at the Johnson Space Center.

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