James Webb Space Telescope Project

CGH Specification for JWST SSDIF CoC Test

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Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and
Space Administration

1.0 SCOPE

This specification establishes the requirements for the Computer Generated Holograms (CGH) to be used during optical testing of the Primary Mirror Segment Assemblies (PMSA) for the James Webb Space Telescope (JWST). Testing will occur at NASA's Goddard Space Flight Center (GSFC) in the SSDIF facility. The CGHs are used to generate a null test wavefront during a double pass interferometric test to characterize the PMSA prescriptions. Specifically, the test will be used to look for changes in the mirror shape as a result of environmental testing at GSFC.

2.0 APPLICABLE DOCUMENTS

The following documents specify the design of each of the three mirror prescriptions and the location of the focused fiducial spots. These drawings should be used along with this specification in the design and fabrication of the CGH.

BATC Drawing 579860	Polished Primary Mirror Segment A
BATC Drawing 579994	Polished Primary Mirror Segment B
BATC Drawing 579995	Polished Primary Mirror Segment C

3.0 PRESCRIPTION

While the primary mirror is comprised of 18 segments there are only three unique prescriptions, A, B, and C, replicated six times each. Each of the three prescriptions has the same radius of curvature and conic constant but a unique off-axis distance. This is because the mirror segments are hexagonal sections from a concave ellipsoid parent surface. The off-axis distance is defined in the referenced drawings and is from the parent vertex to the center of the segment. The surface equation is a standard conic equation defined as follows.

$$z(x,y) = \frac{R^{-1}(x^2+y^2)}{1+\sqrt{1-R^{-2}(1-k)(x^2+y^2)}}$$

R, Radius of Curvature (mm) [Concave]		15899.915
K, Conic Constant		-0.9966605
Off Axis Distance (mm)	A	1325.18298
	B	2638.06969
	C	2288.83286

Table 1. Prescription Values

4.0 CGH SUBSTRATE

The CGH glass substrate will be made from the vendor specified grade of fused silica. The substrate will be 152.4 mm by 152.4 mm (6"x6") nominally. The thickness of the CGH will be accounted for in the design and is assumed to be 6.35 mm nominally. The actual thickness will be reported.

The patterned side of the CGH will face the test optic. The non-patterned side will be AR (anti-reflection) coated for 632.8 nm.

5.0 CGH TYPE

The CGH shall be a phase style with diffraction lines etched into the glass substrate.

6.0 CGH DESIGN

F/#

The CGH will be designed to be used with both an F/6 and F/1.5 interferometer diverger.

Interferometer Focus to CGH Distance

The point source (interferometer focus) to CGH patterned side will be 890 mm.

CGH to Test Optic Distance

This distance will be the same for all A, B, and C prescriptions. The distance from the CGH patterned side to the center of the test optic surface should be 15,163.0 mm. This number may be changed as required by the CGH designer but the A, B, and C prescriptions shall have the same CGH to test optic distance.

Pupil Distortion

Pupil distortion shall be minimized to the extent possible in the CGH design. In order to back out the effects of pupil distortion from the measured data, either an equation will be provided in local test optic coordinates or a set of tables showing ray trace locations on the mirror surface and the CGH plane will be provided.

Ghosting

The CGHs will be designed such that the impact of CGH ghosts, caused by additional diffractive orders, make negligible contribution to the measurement errors.

Test Wavelength

The CGHs should be designed for a standard HeNe interferometer wavelength of 632.8 nm.

7.0 SEPARATION OF DIFFRACTIVE ORDERS

While the CGH substrate will be centered on the interferometer axis, the null pattern should be decentered with respect to that axis. This provides separation of the diffractive orders without tilting the CGH. In other words, the design should force the CGH substrate to be normal to the interferometer collimated beam. This is used to aid the alignment process. Since the CGH will be rotated about the interferometer axis the null pattern decenter should be limited to +/- 15mm from the CGH substrate center with less decenter preferable.

The following explanation may be helpful in understanding the desired CGH design attributes.

> There are two important rays from the interferometer to the null and to the test mirror. The first (Ray 1) is the central ray out of the interferometer. This ray is normal to the interferometer-facing side of the null substrate. It proceeds straight through the null substrate where it encounters the null diffractive pattern on the far side. This ray exits the CGH with both a horizontal and vertical deviation. Ray 1 then hits the PMSA off-center. The second ray (Ray 2) is the ray that hits the physical center of the PMSA. This ray is at an angle, in both the horizontal and vertical directions, with respect to Ray 1 leaving the interferometer focus. It proceeds thru the CGH substrate to hit the null diffractive pattern at its center (i.e. not at the center of the substrate) and leaves the CGH at normal incidence to the surface directly along the segment's axis. This ray then proceeds to the center of the segment.

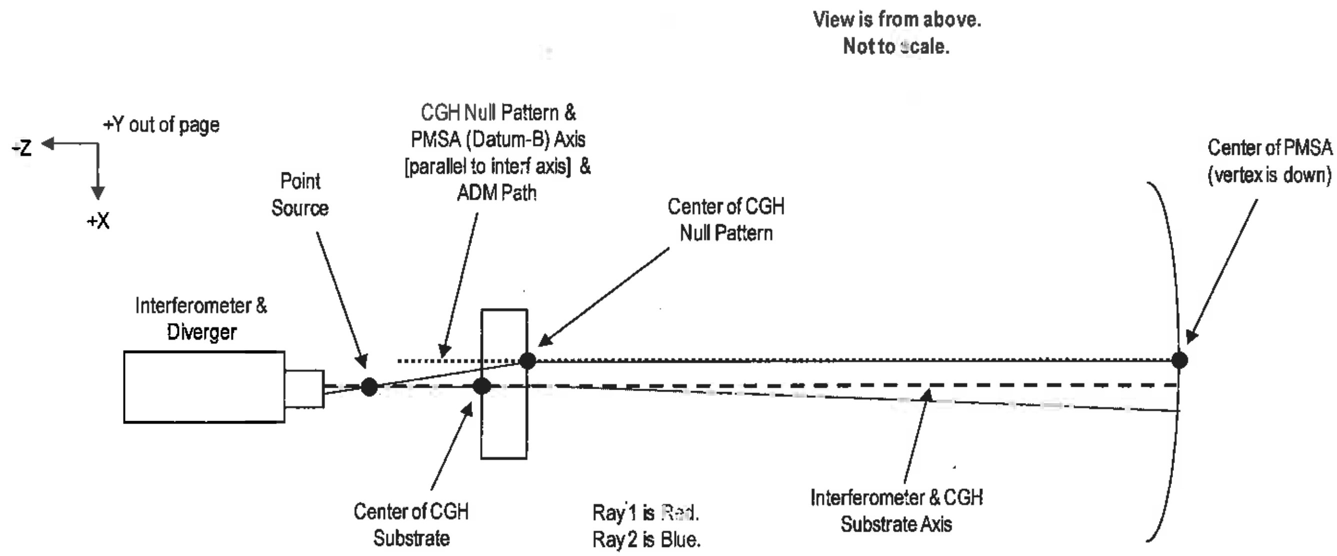

Figure 1: CGH Optical Ray Discussion

8.0 CGH LAYOUT

The CGH will be designed with 3 diffractive zones, null wavefront, retro alignment feature, and projected alignment spots. Additional features as required by the designer may be added as well.

Null Pattern

The null pattern shall be oversized by a several percent to allow for prescription alignment errors. However, the shape of the null pattern will approximately match that of the distorted primary mirror segment in order to maximize the space available for the other CGH layout features.

Retro Pattern

A reflective diffractive pattern will be incorporated to allow the CGH to be aligned to the interferometer. This pattern acts as a spherical mirror with an applicable radius of curvature to set the CGH-to-interferometer focus spacing to the correct value.

Projected Alignment Spots

The design will include diffractive features that focus some of the interferometer light down to spots on the mirror surface. The imaged spots should have the following characteristics:

1. A minimum of 4 spots should be projected onto mirror surface.
2. Spots should be round with approximately ~2.5mm diameter at mirror.
3. Spots should look like airy disk at mirror (if possible).
4. Spots should be in approximately 100mm from edges (so edges don't affect them)
5. The minimum spots should be at the "approximate" locations shown in figure 2.

Below is a diagram showing the location of the fiducial spots relative to each mirror prescription. The diagram also shows the preferred orientation of the PMSA null pattern on the glass substrate relative to the parent vertex.

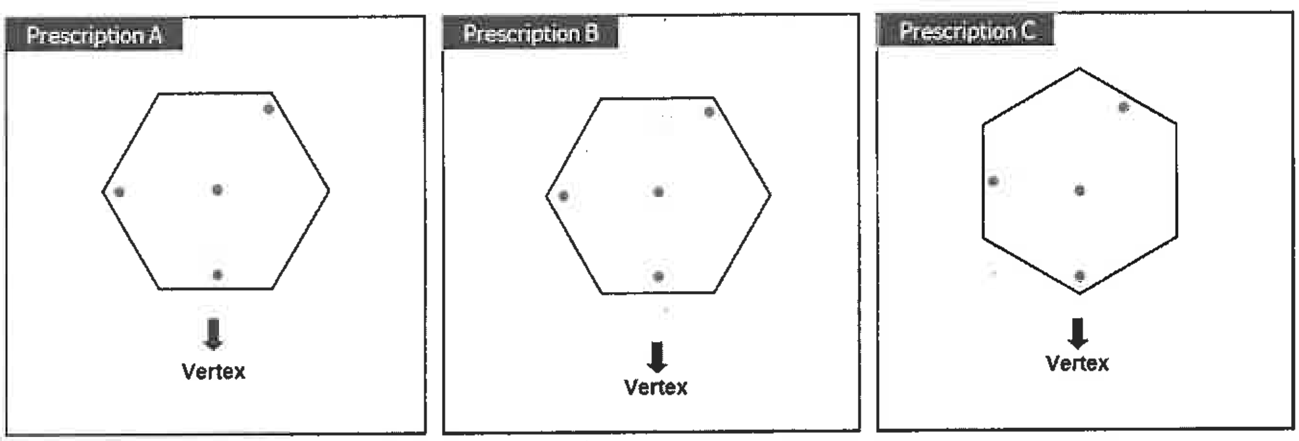

Figure 2: Fiducial spot locations (looking at mirror surface)

9.0 CGH FRAME

The CGH will be supplied with a frame that is capable of interfacing to a Diffraction International 6 DOF mount. If the frame is separate from the glass substrate then the CGH should be bonded into the frame in a low distortion manner. The CGHs should be aligned withing the frames such that each CGH is aligned to one another allowing for minimal realignment when switching between CGHs.

10.0 ADDITIONAL ITEMS

1. The supplier will provide an optical model (preference is CodeV) of the test with the CGH used.
2. The supplier will provide any instructions for use specific to the CGH.
3. The supplier will provide a certification of the CGH and method used to certify.