COS FUV Grating
Holographic Recording Specification

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ABBREVIATIONS & ACRONYMS

Å	Angstroms
CASA	Center for Astrophysics and Space Astonomy
COS	Cosmic Origins Spectrograph
CU	University of Colorado
HST	Hubble Space Telescope
JY	Jobin-Yvon
ppm	Parts Per Million
rms	Root Mean Sum
TBD	To Be Determined
TBS	To Be Specified

1. PURPOSE

This document specifies the holographic recording parameters and the grating performance requirements for the Hubble Space Telescope (HST) Cosmic Origins Spectrograph (COS) G130M, G160M, and G140L FUV gratings. The holographic ruling process will be controlled and conducted by Jobin-Yvon (J-Y).

2. APPLICABLE DOCUMENTS & DRAWINGS

2.1 APPLICABLE DOCUMENTS

COS-08-0001	COS FUV Grating Substrate Specification

2.2 APPLICABLE DRAWINGS & SKETCHES

CASA-COS-1000	Substrate, COS G130M & G160M
CASA-COS-1001	Substrate, COS G140L
CASA-COS-1002	G130M Holographic Recording Geometry
CASA-COS-1003	G160M Holographic Recording Geometry
CASA-COS-1004	G140L Holographic Recording Geometry

3. REQUIREMENTS

3.1 ITEM DESCRIPTION & DEFINITION

FUV grating substrates will be provided to J-Y by CU/CASA. Holographically recorded rulings shall be applied to these substrates. The grating substrates are made of fused silica and incorporate a concave aspherical optical surface, mounting surfaces, and mirrored surfaces for use during installation and alignment of the grating. The substrate dimensions, clear aperture, material, and fiducial marks are presented in drawings CASA-COS -1000 and CASA-COS -1001.

Each substrate shares a common geometry with the exception of the optical prescription. The G130M and G160M gratings utilize the same optical prescription while the G140L grating has a unique prescription. The details of the grating substrate and optical prescriptions can be found in COS-08-0001, however, the optical prescriptions have been included in this document for reference. In the event of a discrepancy in the optical prescriptions presented in this document and COS-08-0001, the values presented in COS-08-0001 shall be considered the only valid values.

3.2 GRATING SUBSTRATE OPTICAL PRESCRIPTIONS

3.2.1 Optical Surface Specifications

Each FUV grating substrate is a symmetric asphere. The base radii for each substrate are as follows:

Substrate	Base Radius
G130M	R = 1652 ± 3 mm
G160M	R = 1652 ± 3 mm
G140L	R = 1613.87 ± 3 mm

The Code V holographic surface coefficients from model are:

Substrate	C67	C68
G130M	1.45789E -9	-4.85338 E -15
G160M	1.45789E -9	-4.85338 E -15
G140L	1.33939E-9	1.48854E-14

C67 = (fourth order term)
C68 = (sixth order term)

3.2.1.1 Aspheric Prescription

The concave aspheric substrate is described by the aspheric equation shown below. R is in mm.

$$Z = \frac{CUY\,?X^2}{1+\sqrt{\left\{1-CUY^2\,?X^2\right\}}} + C67\,?X^4 + C68\,?X^6$$

Z = sag of the surface in mm
CUY = 1/R where R is the base radius of the asphere.
X = radial distance from the center of the asphere

3.3 HOLOGRAPHIC RECORDING PARAMETERS

3.3.1 G130M Holographic Recording & Operational Parameters

Parameter	Value
Characteristic Groove Density	3800 g/mm
Operational Bandpass	1150-1450 Å
Blaze Wavelength	1300 Å ± 100 Å
Recording Laser Wavelength	4880 Å
γ	-71.0 deg. ± 1 arcmin
δ	65.3512 deg. ± 1 arcmin
θ_Z	0 ± 3 arcmin
Rc	-4813.92 mm ± 1 mm
Rd	5238.29 mm ± 1 mm

3.3.2 G160M Holographic Recording & Operational Parameters

Parameter	Value
Characteristic Groove Density	3093.3 g/mm
Operational Bandpass	1405-1774 Å
Blaze Wavelength	1600 Å ± 100 Å
Recording Laser Wavelength	4880 Å
γ	-62.5 deg. ± 1 arcmin
δ	38.5004 deg. ± 1 arcmin
θ_Z	0 ± 3 arcmin
Rc	-4363.6 mm ± 1 mm
Rd	4180.27 mm ± 1 mm

3.3.3 G140L Holographic Recording & Operational Parameters

Parameter	Value
Characteristic Groove Density	480 g/mm
Operational Bandpass	1230-2050 Å
Blaze Wavelength	1400 Å ± 100 Å
Recording Laser Wavelength	4880 Å
γ	10.000 deg. ± 1 arcmin
δ	24.0722 deg. ± 1 arcmin
θ_Z	0 ± 3 arcmin
Rc	3674.09 mm ± 1 mm
Rd	3305.19 mm ± 1 mm

3.3.4 Drawings

Drawings CASA-COS-1000, CASA-COS-1001, CASA-COS-1002, CASA-COS-1003, and CASA-COS-1004 are included as part of this specification. These drawings show the grating substrate designs and how each substrate is oriented with respect to the holographic recording geometry.

3.3.5 Grating Coating

After the holographic ruling fabrication process is complete, the grating will require a metallic coating for performance testing. The only allowable optical coating shall be vapor deposited aluminum (VDA). Binding layers below the VDA are acceptable provided they will not degrade the VDA.

3.3.6 Grating Performance Requirements

3.3.6.1 Groove Efficiency

The groove efficiency of the grating shall be measured at a minimum of 3 to 5 wavelengths which cover the majority of the operational bandpass of the grating. Potential wavelengths to be used are as follows:

Grating	Potential Test Wavelengths
G130M	1048Å, 1216Å, 1610Å
G160M	1216Å, 1610Å, 1810Å
G140L	1216Å, 1610Å, 1810Å, 1900-2050Å

The measurements may be done at a single position on the grating using narrow beam illumination. The groove efficiency of the G130M and G160M gratings shall be ≥ 0.45 at all wavelengths within the operational bandpass. The groove efficiency of the G140L grating shall be ≥ 0.30 at all wavelengths within the operational bandpass. The groove efficiency of the grating is defined to be the measured efficiency of the grating divided by the measured reflectivity of a witness mirror coated simultaneously with the optic under test.

3.3.6.2 Blaze Function

The blaze function of the grating shall be measured and/or demonstrated. Each grating has a unique blaze wavelength as presented in Sections 3.3.1, 3.3.2, and 3.3.3. The measurement of the blaze function can be derived using the data acquired during the measurement of the groove efficiency (section 3.3.4.1) or through a direct measurement of the blaze angle of the groove facets through atomic force microscopes or suitable measurement technique. The efficiency of the grating must reach a maximum within ±100 Å of the design blaze wavelength.

3.3.6.3 Scattered Light

The scattered light of each grating shall be measured. The scattered light can be measured at a single point on the grating using a narrow beam to illuminate a portion of the grating. The measurement may be done at a suitable wavelength within the operating bandpass of the grating. The scattered light off the grating shall be ≤ $2X10^{-5}$/Å within 10 Å from line center when measured with a monochromatic pencil beam and a goal of ≤ 10^{-5}/Å within 10 Å from line center for the G130M and G160M gratings. For the G140L grating the scattered light off the grating shall be ≤ $2X10^{-5}$/Å within 50-80Å from line center when measured with a monochromatic pencil beam and a goal of ≤ 10^{-5}/Å within 50-80Å from line center. The scattered light tests may be conducted using 3510Å light.

3.3.6.4 Ghost Images

The intensity of any ghost image shall be less than 10^{-4} of any parent image and shall be demonstrated through testing.

3.3.6.5 Polarization

There are no requirements on the performance of the holographic rulings pertaining to polarization.

3.4 ENVIRONMENTAL REQUIREMENTS

Performance of the holographic gratings shall not be degraded when exposed to the following environmental conditions:

3.4.1 Operating:

Temperature	15° C to 25° C
Relative humidity	0% to 50 %
Pressure	8 x 10^2 Torr to <1 x 10^{-5} Torr

3.4.2 Storage/Handling:

Temperature	-10° C to 40° C
Relative humidity	0 % to 95 % (55 % after coating)
Pressure	8 x 10^2 Torr to <1 x 10^{-5} Torr

3.4.3 Solvents

The grating substrate may not come into contact with any solvent or substance which could damage the optic in any way prior to the holographic recording process. Such substances include, but are not limited to all alcohols and water.

3.4.4 Radiation Susceptibility

The grating must be able to withstand 16 Krad of exposure over an 8 year lifetime with no degradation in the optical or mechanical quality of the substrate.

3.4.5 Silicones

The exposure of the grating to silicones during any activity during its fabrication process shall be minimized. The presence of silicones in an epoxy bond can drastically reduce the strength of the bonded interface. The COS gratings, when complete, will be bonded into their respective mounts prior to final alignment. Since removal of silicones is extremely difficult the exposure of the grating substrates to silicones shall be minimized where practical.

3.5 SHIPPING & HANDLING

3.5.1 Handling

The polished, but yet unruled, grating blank may be handled outside of a class 1000 cleanroom, provided individuals handling the optic are gloved and wear masks.

Once the grating blank has been recorded and coated with Al, it shall be handled only by gloved and gowned individuals in an environment exceeding class 100,000 in particulate cleanliness or a high quality test environment with appropriate handling procedures (e.g. use of gloves, frocks, masks, etc.).

3.5.2 Shipping

The optic is to be stored and shipped in a shipping container provided by CU/CASA at all times after the polishing is complete. The grating can only be shipped with the container backfilled with high purity gaseous nitrogen. GN2 from an LN2 boil-off system is acceptable provided the GN2 from the distribution system has been certified to be 99.999% GN2 with < 25 ppm hydrocarbon content.

4. ACCEPTANCE & VERIFICATION TESTING

4.1 ACCEPTANCE TEST PROCEDURE

The supplier shall prepare an acceptance test procedure (ATP) including the following as minimum.

a. Groove efficiency versus wavelength.
b. STM (scanning tunneling microscope or equivalent) images of the groove profiles of a representative sample or flight optics.
c. Measurement or demonstration of the blaze angle.

The tests shall be adequate to verify that the grating satisfies the requirements of this specification. This ATP shall be submitted to CU for approval at least four weeks prior to acceptance testing.

4.2 ACCEPTANCE TEST

The supplier shall perform an acceptance test, which may be witnessed by the responsible CU optical engineer and QA representative for each flight optic. Data packages must be available for review at the acceptance test but may be submitted to CU within four weeks of acceptance. Other parameters may be verified by data review of previously performed tests and review of as built mechanical data or in process logs. The supplier shall notify CU at least 3 weeks in advance of each acceptance test. Multiple optics may be tested during the same acceptance test.

4.2.1 Specification Verification Matrix

Section	**Description of Requirement**	**Method of Verification**	**Verification of Deliverable**
3.3.1	G130M Blaze Wavelength		
3.3.2	G160M Blaze Wavelength		
3.3.3	G140L Blaze Wavelength		
3.3.4	Grating Coating		
3.3.6.1	Groove Efficiency		
3.3.6.2	Blaze Function		
3.3.6.3	Scattered Light		
3.3.6.4	Ghost Images		
3.4.3	Solvents		
3.4.4	Radiation Susceptibility		
3.4.5	Silicones		

5. WITNESS SAMPLES

CU/CASA will provide five witness samples with each substrate delivered to J-Y. The supplier shall return a minimum of five witness samples per deliverable flight optic. Each witness sample shall be processed in a manner consistent with witness sample processing matrix presented below. The witness samples will have the following dimensions:

Diameter	25.4 mm ± 0.25 mm
Thickness	3.18 mm ± 0.25 mm
Clear Aperture Diameter	20.32 mm minimum
Bevel	45 deg edge bevel
Surface figure	_ 1λ PV
Surface finish	Best commercial polish (_ 30 Å rms goal)

5.1 WITNESS SAMPLE PROCESSING MATRIX

Witness Sample #	Application/ Removal of Photoresist	Ion etch	Cr/VDA Optical Coating
1	x	x	x
2			x
3			x
4			x
5			x