COS FUV Grating
Substrate Specification

Date:	July 22, 1998
Document Number:	COS-08-0001
Revision:	Initial Release
Contract No.:	NAS5-98043
CDRL No.:	N/A

Prepared By: _____ _____
E. Wilkinson, COS Instrument Scientist, CU/CASA — Date

Reviewed By: _____ _____
R. Cahill, Optical Designer, BATC — Date

Approved By: _____ _____
D. Hood, Program Manager, BATC — Date

Approved By: _____ _____
J. Andrews, COS Experiment Manager, CU/CASA — Date

Approved By: _____ _____
J. C. Green, COS Principal Investigator, CU/CASA — Date

Center for Astrophysics & Space Astronomy
University of Colorado
Campus Box 593
Boulder, Colorado 80309

REVISIONS

Letter	ECO No.	Description	Check	Approved	Date
		Initial Release			

Original Release Name	Date
Drawn: E. Wilkinson	7-22-98
Reviewed:	
Approved:	

THE UNIVERSITY OF COLORADO
At Boulder
The Center for Astrophysics and Space Astronomy

COS FUV Grating Substrate Specification

Size	Code Indent No.	Document No.	Rev
A		COS-08-0001	-
Scale: N/A			

Table of Contents

ABBREVIATIONS & ACRONYMS

Å	Angstroms
ATP	Acceptance Test Procedure
CASA	Center for Astrophysics and Space Astronomy
COS	Cosmic Origins Spectrograph
CU	University of Colorado
HST	Hubble Space Telescope
JY	Jobin-Yvon
rms	Root Mean Sum
TBD	To Be Determined
TBS	To Be Specified

1. PURPOSE

This specification defines the requirements for manufacture, performance, and verification testing of the FUV grating substrates for the Hubble Space Telescope's (HST) Cosmic Origins Spectrograph (COS). This specification does not include any details regarding the holographic rulings which will be applied after substrate fabrication. The COS requires two types of fused silica substrates, one type will be used to produce the two high resolution gratings G130M and G160M. The second substrate will be used to produce the low resolution G140L grating.

2. APPLICABLE DOCUMENTS & DRAWINGS

2.1 APPLICABLE DRAWINGS

CASA-COS-1000	Substrate, COS G130M & G160M
CASA-COS-1001	Substrate, COS G140L

3. REQUIREMENTS

3.1 ITEM DESCRIPTION & DEFINITION

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 gratings into the COS instrument. The grating blank dimensions, clear aperture, material, and fiducial marks are presented in drawings CASA-COS-1000 and CASA-COS-1001.

3.2 OPTICAL REQUIREMENTS

3.2.1 Optical Surface Specifications

3.2.1.1 Base Radii

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

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

3.2.1.2 Aspheric Coefficients

The Code V holographic surface coefficients from model (grating coefficients omitted) 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 -13

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

3.2.1.3 Aspheric Prescription

The concave aspheric substrate shall be described by the aspheric equation shown below. R is in mm. The signs have been set to give the sag as a positive value to match the output of the Code V Sag function.

$$Z = \frac{CUY \cdot X^2}{1 + \sqrt{\{1 - CUY^2 \cdot X^2\}}} + C67 \cdot X^4 + C68 \cdot X^6$$

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

3.2.2 Clear Aperture

3.2.2.1 Aspherically Figured Clear Aperture

The aspherically figured clear aperture shall be as specified in drawing CASA-COS-1000 for the G130M and G160M substrates and in drawing CASA-COS-1001 for the G140L substrates.

3.2.2.2 Optical Requirements Outside the Aspherically Figured Clear Aperture

The area outside the aspherically figured clear aperture for each grating substrate will be used to precisely position the substrate in the holographic recording fixture. This requirement places a constraint on the knowledge of the relationship between the aspheric surface within the clear aperture and the polished surface surrounding the clear aperture. The departure from the controlled surface, i.e. within the 79 mm diameter clear aperture, outside the clear aperture shall deviate from the design surface by less than 5 microns.

The area outside the clear aperture shall also have a polished surface with a surface roughness of < 20 Å rms. There is no scratch and dig requirement for the area outside the clear aperture.

3.2.3 Substrate Surface & Finish

3.2.3.1 Surface Figure

The fused silica grating substrate shall have a surface figure of ≤ λ/50 rms over the entire clear aperture measured at 6328 Å. This specification shall be met over the following spatial frequencies:

Surface Error Bandwidths	
Surface Errors	Spatial Frequencies
Surface Figure	> 1 mm
Surface roughness	< 0.5 mm

3.2.3.2 Surface Roughness

The clear aperture of each grating substrate must have a surface roughness < 7-10 Å rms.

3.2.3.3 Scratch and Dig

The polished clear aperture shall meet or exceed a Scratch & Dig specification of 20-10 per MIL-O-13830H.

3.2.4 Wedge, Offsets, and Substrate Thickness

3.2.4.1 Wedge

The wedge shall be ≤ 30 arc sec with knowledge to 3 arcsec. For the aspheres, wedge is defined as the complement of the angle between the plane defined by the fiducial surface on the back of the substrate and the normal to the asphere vertex.

3.2.4.2 Offsets

The center of the asphere shall be within ± .2mm of the geometric center of the grating substrate.

3.3 MECHANICAL

3.3.1 Substrate Material

The grating blanks shall be fabricated from fused silica, Corning 7980, inclusion class 0, grade F or better.

3.3.2 Non-Optical Surface Finish

All non-optical surfaces shall be finished with a non-specular surface to support holographic recording of the finished grating substrate. This requirement will be satisfied via 2 processes. All non-optical, planar surfaces will be finished using 40μm alumina grit and standard polishing methods. All non-optical, cylindrical surfaces will be finished with a R180 fixed abrasive grinding tool with a silicone-free oil lubricant.

3.3.3 Dimensions

Physical dimensions of the grating substrates shall be per Drawings CASA-COS-1000 and CASA-COS-1001.

3.3.3.1 Dimensional Knowledge

Optics diameters shall be measured and recorded to a precision of 0.0025 mm. Center thickness shall be measured and recorded to a precision of 0.025 mm

3.3.4 Fiducials

Fiducials on the substrates shall be provided in the locations shown on Drawings CASA-COS-1000 and CASA-COS-1001. Fiducials may be scribed. Fiducials shall be 0.002" to 0.004" wide.

3.3.5 Serialization & Marking

The grating substrates shall be identified by a serial number to retain identification. The serial number shall be sand blasted on the side of the finished element in the location shown on drawings CASA-COS-1000 and CASA-COS-1001. Since the grating substrates will be subjected to a vacuum environment, the marking method shall not outgas in this environment. Marking method shall be approved by CU prior to application. Witness samples are to be scribed on the backside with the letters CW followed by a simple number, i.e. CW 23.

3.4 ENVIRONMENTAL REQUIREMENTS

During the fabrication of the grating substrates defined in this document no process or materials shall be employed which would preclude the substrate from meeting or exceeding the operational specifications under the environmental conditions presented in Section 3.4.1. The environmental conditions under which the substrate performance must be verified are outlined in Section 4, Acceptance & Verification Testing, of this document.

3.4.1 Operating:

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

3.4.2 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 a substance would be hydroflouric acid.

3.4.3 Silicones

The exposure of the grating substrate to silicones during any activity during it's 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 must be minimized where practical. Should the grating substrate knowingly be exposed to silicones during the fabrication process, the manufacturer shall notify CU/CASA in writing.

3.5 SHIPPING & HANDLING

3.5.1 Handling

During all phases of substrate fabrication suitable precautions must be employed during handling of the optic to insure that it is not damaged in any way which would preclude use of the substrate as a holographically ruled diffraction grating in the COS instrument.

3.5.2 Shipping

At the time of delivery the substrate must meet or exceed class 1000 cleanroom specifications. The clean substrate will be shipped in a shipping container that also meets or exceeds class 1000 cleanroom specifications during installation of the substrate into the shipping container.

3.5.3 Shipping/Handling Environmental Restrictions

The completed blank must be maintained within the following environmental limits:

Temperature	-50 to 100°C
Humidity	≤ 95% relative humidity
Pressure	< 800 Torr.

4. ACCEPTANCE & VERIFICATION TESTING

4.1 ACCEPTANCE TEST PROCEDURE

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

a) Test to be performed and description of accomplishment method.
b) Sequence of tests.
c) Article being tested (i.e., flight article or witness sample).
d) Equipment to be used.
e) Accuracy of measurement.
f) Calibration techniques (as appropriate).
g) Data sheets.

The tests shall be adequate to verify that the mirror satisfies the requirements of this specification per the specification verification matrix shown in Section 6.0 of this document. The 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 of each flight optic. Data packages must be available for review at the acceptance test but may be submitted to CU at a later date. Interferometric and radius of curvature tests must be witnessed. 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 1 week in advance of each acceptance test. Multiple optics may be tested during the same acceptance test.

A redundant verification test of the optical prescription within the clear aperture is also required (sections 3.2.1.1, 3.2.1.2, 3.2.1.3)

CU retains the right for any responsible CU optical engineer, QA representative associated with the HST/COS project, or US government representative to witness any and all acceptance tests; however, it is anticipated that this will occur on a limited basis to accept and approve the ATP.

4.3 ACCEPTANCE TEST ENVIRONMENTAL CONDITIONS

Acceptance testing of the grating may be conducted under normal laboratory operating conditions provided they fall within the environmental limitations presented in Sections 3.4.1 and 3.5.3 It is anticipated that the grating substrates will be tested at 22.5°C ± 2°C.

4.4 SPECIFICATION VERIFICATION MATRIX

Section	Description of Requirement	Method of Verification	Verification of Deliverable
3.2.1.1	Base Radii		
3.2.1.2	Aspheric Coefficients		
3.2.1.3	Aspheric Prescription		
3.2.2.1	Aspherically Figured Clear Aperture		
3.2.2.2	Figure Outside Clear Aperture		
3.2.3.1	Surface Figure		
3.2.3.2	Surface Roughness		
3.2.3	Scratch & Dig		
3.2.4.1	Wedge		
3.2.4.2	Offsets		
3.2.4.3	Substrate Thickness		
3.3.1	Material		
3.3.2	Non-Optical Surface Finish		
3.3.3	Dimensions		
3.3.3.1	Dimensional Knowledge		
3.3.4	Fiducials		
3.3.5	Serialization & Marking		
3.4.1	Operating Environments		
3.4.3	Solvents		
3.4.4	Silicones		

5. WITNESS SAMPLES

The supplier shall provide a minimum of five witness samples per deliverable flight optic. Each witness sample shall be made from the same material (lot) as the specified substrate. The witness samples shall have their coated surface polished flat in a similar manner as the optical element specified herein. These witness samples shall be delivered along with the mirrors to CU. The witness samples shall 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)