COS G130M FUV Grating Calibration And Qualification Plan

Date:	October 11, 1999
Document Number:	COS-01-0002
Revision:	Initial Release
Contract No.:	NAS5-98043
CDRL No.	AV-02

Prepared By: ____________________ ________
S. Osterman, COS Optical Scientist, CU/CASA Date

Reviewed By: ____________________ ________
E. Wilkinson, COS Instrument Scientist, CU/CASA Date

Approved By: ____________________ ________
J. Andrews, COS Experiment Manager, CU/CASA Date

Approved By: ____________________ ________
J. Green, COS Principal Investigator, CU/CASA Date

Reviewed By: ____________________ ________
R. Cayhill, COS Optical Designer, BATC Date

Approved By: ____________________ ________
D. Hood, COS Program Manager, BATC 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: S. Osterman	10-11-99
Reviewed:	
Approved:	

THE UNIVERSITY OF COLORADO

At Boulder

The Center for Astrophysics and Space Astronomy

COS G130M FUV Grating Calibration
And Qualification Plan

Size	Code Indent No.	Document No.	Rev
A		COS-01-0002	-
Scale: N/A			

Table of Contents

Abbreviations and Acronyms

Å	Angstroms
ARL	CASA Astrophysical Research Laboratory
ATP	Acceptance Test Procedure
BASD	Ball Aerospace Systems Division
CASA	Center for Astrophysics and Space Astronomy
COS	Cosmic Origins Spectrograph
CU	University of Electronics
FUSE	Far Ultraviolet Spectroscopic Explorer
HST	Hubble Space Telescope
GROVER	Grating Optical Verification Equipment/Reflective
LASP	Laboratory for Atmospheric and Space Physics
STB	Space Technology Building

1. SCOPE

This document describes the objectives for the G130M grating evaluation tests and provides an overview of the tests to be performed. Where detailed procedures are appropriate, additional documentation will be provided prior to initialization of those activities. Included in Section 2.1 is a list of assembly and test procedures.

The purpose of these tests is to determine if the candidate gratings perform within specification across the nominal bandpass (1150Å – 1450Å) and to assist in selecting the flight grating from amongst the candidate gratings. The tests fall into three categories: Imaging and Resolution Tests, Efficiency Tests, and Scattered Light Tests. The objectives, hardware and data reduction methods used for each test are listed in section 3, and are summarized briefly here:

Test	Optical Configuration	Requirement	Test Points
Imaging and Resolution	Modified Rowland Circle – Flight-like illumination using GROVER abberated source to simulate HST optical system.	Demonstrate at least 20,000 resolution across bandpass. If possible, data will be used to select flight optic.	3 wavelengths separated by no more than 100Å and no less than 50Å
Grating Efficiency	Wadsworth configuration. 3-5mm beam illuminates limited area of grating at several locations with grating angle and detector position adjusted to simulate flight illumination angle of incidence.	Demonstrate that grating efficiency is above specification and determine efficiency in sufficient detail to aid flight optic selection.	3×3 grid and 5 wavelengths separated by no more than 75Å
Grating Scatter	Analysis of data acquired in imaging and efficiency tests.	Demonstrate that grating scatter is $\leq 2\times10^{-5}$/Å 10Å away from test line.	Analysis of at least two test points

In addition to these tests, an effort will be made to measure the positions of the optic and the detector relative to the GROVER prime focus and optical axis after imaging testing to provide additional alignment information for the program.

2. APPLICABLE DOCUMENTS AND DRAWINGS

2.1 APPLICABLE DOCUMENTS

Document #	**Title**
COS-8-0001	COS FUV Grating Substrate Specification
COS-8-0002	COS FUV Grating Holographic Recording Specification
PO-TR-JOB-COS.1301	Acceptance Data Package Diffraction Grating G130M B
PO-TR-JOB-COS.1302	Acceptance Data Package Diffraction Grating G130M C
IN0090-111	Preliminary Cleanliness and Contamination Control Plan for the Cosmic Origins Spectrograph (COS)
NSI 33-07-1101	Grover Alignment And Test Report
	HST/COS Information Package for G130M-B Grating (Grating Coating Report)
	HST/COS Information Package for G130M-C Grating (Grating Coating Report)
	HST Independent Verification Team Report on the Optical Alignment and Verification of GROVER
COS-OPT-011	Optical Witness Mirror Plan for COS
SCM-1050	Verification Procedures and Reports
COS-ATP-001	Pre-Grating Testing End-to-End Test
COS-ATP-002	COS FUV Grating Test – Grating Mounting Procedure
COS-ATP-003	COS FUV Grating Test – Grating Demounting Procedure
COS-ATP-004	COS FUV Grating Testing – Optical Prealignment
COS-ATP-005	COS FUV Grating Testing – Post Test Metrology
COS-ATP-006	COS FUV Grating Testing – G130M Imaging and Resolution Testing
COS-ATP-007	COS FUV Grating Testing – G130M Efficiency Testing
COS-ATP-008	COS FUV Grating Testing – G130M Grating Scatter Measurement

2.2 APPLICABLE DRAWINGS

Drawing #	**Title**	**Revision**
CASA-COS-1000	COS Grating Substrate – G130M, G160M	Current Rev.

3. FUV GRATING EVALUATION

COS grating tests will be performed in the CASA ARL integration and test facility. This consists of an 11.0 ft diameter by 14.0 ft long vacuum chamber opening into a class 1000 clean room. Because all tests are to be performed in the far ultraviolet, all tests must be performed in the vacuum chamber. The vacuum chamber is fitted with a removable 10ft by 5 ft vibrationally isolated optics table on which the grating and all grating test equipment is mounted.

3.1 IMAGING AND RESOLVING POWER CHARACTERIZATION

3.1.1 Overview

The FUV gratings are designed to correct for the HST aberration. Consequently, it is necessary to illuminate the gratings with a similarly aberrated UV light source in order to accurately assess the grating imaging and dispersion characteristics. This is accomplished by using the GROVER optical system developed by Kevin Redman. The GROVER system is described in NSI document 33-07-1101. The light source for GROVER is a sealed hollow cathode platinum lamp. This was selected both for ease of operation in a vacuum chamber, and because it is not afflicted with the inherent line broadening of most other UV light sources.

3.1.2 General Test Setup

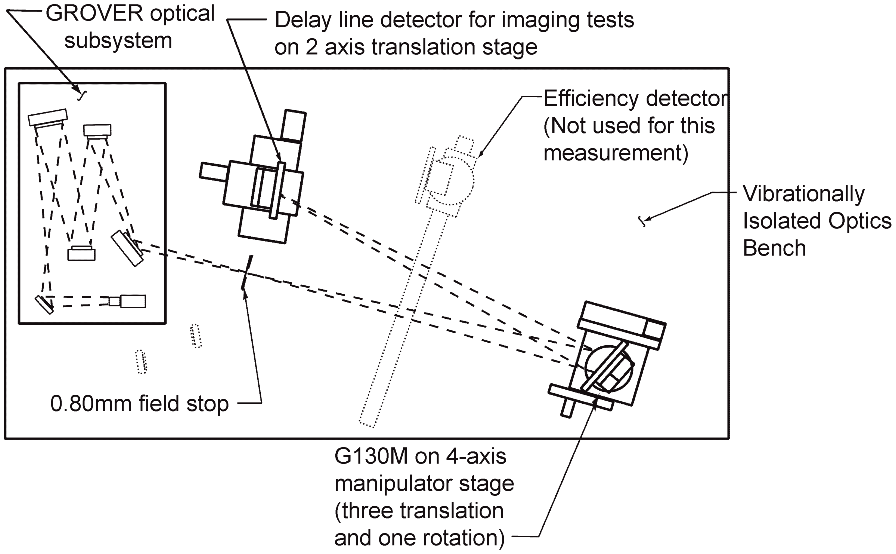


Figure 3.1 G130M imaging test setup

The general layout of the optics table for the image testing is shown in Figure 3.1. Light from the GROVER optical subsystem illuminates the test optic, which then diffracts the light onto a Siegmund Scientific delay line detector with 25micron resolution in the dispersion direction. The GROVER system is placed so that it fully illuminates the test optic with the GROVER prime focus the same distance from the grating center as the HST prime focus would be on orbit. The test optic is rotated to the nominal angle α and the detector is then located so as to be tangent to the Rowland circle at the nominal β value (taking into account the non-classical geometry of COS) and at the required distance from the test optic. (Note that the entrance aperture and the grating surface for COS do not lie on the Rowland circle, but rather outside and inside of the Rowland circle, respectively, and that the nominal β angle is 0.9° less than for a classical Rowland circle mount). The location of the test optic and the detector relative to the GROVER prime focus and optical path are initially determined using theodolite metrology and knowledge of the GROVER system acquired prior to delivery of the system. Fine adjustment of the focus is accomplished by translating the grating and detector during vacuum testing. The focal plane of the detector is not curved to match the focal surface of the grating. Consequently, once the best focus is determined at one wavelength, the detector must be translated both tangent to and along the beam path in order to optimize the image for any other wavelength. Images will be optimized and analyzed at three wavelengths separated by no more than 100Å.

3.1.3 Optical Metrology

The optical system is prealigned using three Wild T-3000A theodolites connected to a computer controlled metrology system and two independent autocollimating theodolites. The detailed alignment procedures are described in NSI document 33-07-1101. The system allows placing the test optic and detector to within 0.1mm and 5 arc seconds of the nominal positions with the various translation stages set to the center of their range of travel.

3.1.4 GROVER Qualification

See NSI document 33-07-1101.

3.1.5 Data Archiving Plan

The following data are archived directly to disk: Detector images, micropositioning stage positions and commands, vacuum chamber parameters and QCM data. GROVER lamp current and detector electronics temperature are manually recorded. All test data will be transferred to a single machine (TBD) and backed up on a regular basis. In addition, extensive notes will be taken as a part of all measurement processes. For additional information, see Appendix B, COS Grating Testing Data Archive File Structure.

3.1.6 Data Analysis Plan

Images will be saved as photon lists (x-y positions of individual events). Images are reconstructed and will be examined to identify several emission lines in the vicinity of the selected analysis line. Images will be compared to ray trace data and when the proper profiles are achieved and the apparent line widths minimized, images will be straightened to remove any astigmatism using the FUSE Display software package and the line profiles will be fit to a Gaussian. The known emission lines will be used to determine a local dispersion relation in pixel space. The resolution will then be determined by comparing the observed line width in pixels to the local dispersion relation without reference to the plate scale of the detector, as this is less well known than the wavelengths of the reference emission lines. This analysis will provide an approximate estimate of the grating dispersion relation and a reasonable lower limit on the grating resolution. Details of the data reduction and error analysis will appear in the grating test reports.

3.1.7 Success Criteria

Efforts will be made to obtain the highest resolution images possible to establish a lower limit on the grating resolving power. One of the two goals of these tests is to demonstrate that the optic is within specification. The second goal is to provide data to help select the flight optic from the two provided.

3.2 EFFICIENCY CHARACTERIZATION

3.2.1 Overview

The purpose of these tests is to determine the grating efficiency of the G130M optic by measuring the efficiency of a small portion of the optic at nine points spanning 50% of the blazed surface and forming a 3×3 grid. Measurements will be performed at five wavelengths within the nominal bandpass separated by no more than 75Å. The grating will be illuminated by a quasi-parallel, 3-5mm diameter monochromatic beam at the desired test wavelength.

3.2.2 General Test Setup

The test detector (Quantar model 3391A MCP imaging detector) will be placed on an URM-100 rotation stage on top of a GV-88 translation stage. The translation and rotation stage will allow the detector to be either positioned between the test optic and the light source viewing the direct beam or close to the Wadsworth focus for the test grating. The GV-88 translation rail will be set so that it is roughly tangent to the Rowland circle at the nominal wavelength. Care will be taken to ensure that the same portion of the detector is illuminated in both configurations and at the same angle of incidence. Additionally, the spatial response of the detector will be mapped to confirm that variations in spot size will not introduce a significant systematic error. Note that if this is expected to introduce a substantial error, then the rail will be moved so that the detector is well beyond the Wadsworth focus. Grating rotation will be adjusted to simulate flight illumination for each of the three points on a horizontal scan. Grating tilt must be manually adjusted between vertical rows in order to ensure that the detector is properly illuminated. Care must be taken to ensure that the detector is illuminated at the same angle of incidence for all measurements.

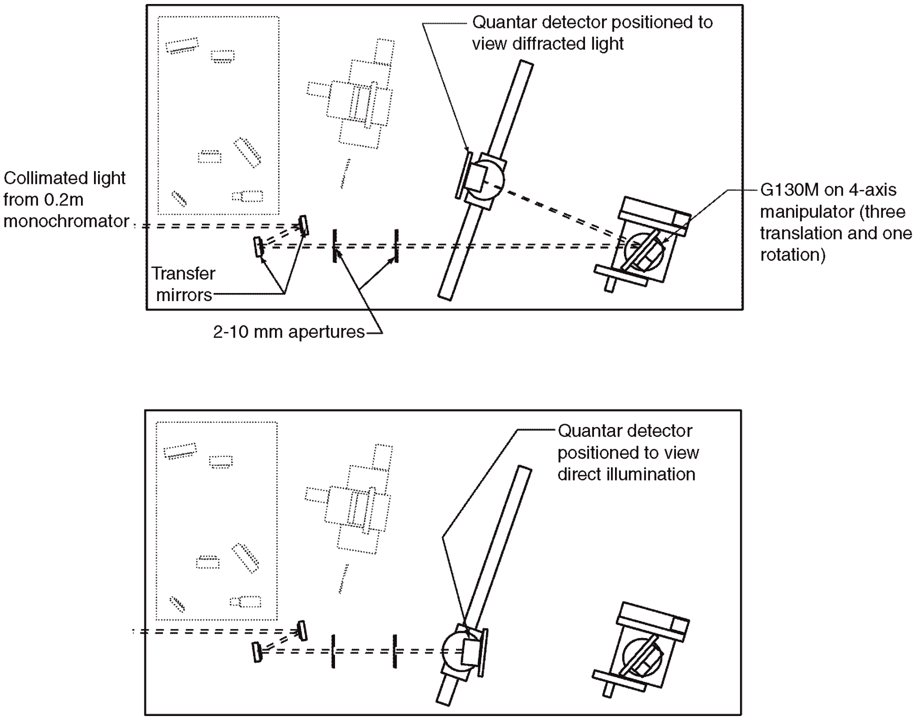


Figure 3.2 G130M efficiency measurement layout

3.2.3 Description of Measurements

The general layout of the optics table for the efficiency tests is shown in Figure 3.2. The grating will be tested at five wavelengths at each point spanning the nominal first order bandpass of the test optic. The grating will be illuminated either by a flowing gas discharge lamp or a hollow cathode platinum lamp via an ARC VM-502 0.2M monochromator. Each set of test data (spatial and wavelength) will consist of a dark count measurement, a direct beam illumination, a diffracted beam illumination, a second direct beam illumination and a final dark count measurement, recorded in rapid succession (in the order stated). All sets will include at least 10K counts in the diffracted image if possible in order to achieve 1% statistics. If the direct beam illumination data sets indicate a greater than 2% drift in source output, or the dark count rate change substantially between the initial and final dark count measurements, the test will be repeated.

3.2.4 Detector Interface Linearity and Response

The detector interface has been tested for linearity and has been shown to exhibit less than 1% nonlinearly at count rates below1500 Hz. All tests will be performed in this range. The detector interface linearity test report is included as an appendix to this document.

3.2.5 Source Stability

Both the flowing gas discharge and the platinum hollow cathode sources will be tested for photometric stability prior to initiation of the testing, and each data set will include two direct illumination sets to test for lamp output drift.

3.2.6 Data Archiving Plan

The following data are archived directly to disk: Detector images, micropositioning stage positions and commands, vacuum chamber parameters and QCM data. Monochromator settings and lamp operating parameters are manually recorded, both in the image headers and in the operator's notebook. All test data will be transferred to a single machine (TBD) and backed up on a regular basis. In addition, extensive notes will be taken as a part of all measurement processes. For additional information, see Appendix B, COS Grating Testing Data Archive File Structure.

3.2.7 Data Analysis Plan

The following images will be recorded for each test wavelength and grating position: (1) An initial dark (background) image (I_{B-1}). (2) Immediately following this, the initial direct image will be recorded image (I_{D-1}). (3) The detector will be translated to view the light diffracted by the grating into the first order and this image will be recorded (I_G). (4) The detector will be returned to the location where the initial direct image was recorded and a second direct image will be recorded (I_{D-2}). (5) Finally, a second background image will be recorded (I_{B-2}).

The direct and diffracted images will be inspected to confirm that the same region of the detector is illuminated for each image. All images will then be analyzed to determine the count rate by dividing the counts in the selected area by the in the selected by the image's integration time and applying the appropriate detector interface and electronics dead time correction (C_{D-1}, etc.). The countrates for each illuminated image is background corrected by subtracting the average background, and the two direct images are averaged. The efficiency is then the ratio of the diffracted to the direct illuminated count rates.

3.2.8 Success Criteria

Measured efficiency should be in good agreement with the efficiency estimated from the groove efficiency measured at JY and the reflectivity measured at GSFC.

3.3 SCATTERED LIGHT CHARACTERIZATION

3.3.1 Overview

Images obtained for the efficiency and imaging tests will be examined for data with sufficiently isolated lines to provide an upper limit on grating scatter. The efficiency test data should provide an adequate data set, although it will be obtained in a Wadsworth configuration for a small portion grating area. If necessary, a smaller aperture will be placed in the efficiency beam line. Also, if the efficiency data is to be taken with the detector beyond the Wadsworth focus for the grating, then the efficiency detector will have to be relocated to the Wadsworth focus to obtain a sufficiently sharp image.

3.3.2 Data Archiving Plan

See section 3.2.6

3.3.3 Data Analysis Plan

Data from the efficiency test will be analyzed to first establish a plate scale (dispersion equation) based on a rich local spectral region. Then a well isolated line will be selected and the diffracted image will be analyzed taking into account natural line width, defocus due to imprecise detector location and grating curvature, detector background and test facility scattered light.

3.3.4 Success Criteria

Scatter must be demonstrated to be less than or equal to 2×10^5Å as measured 10Å away from the test line at two positions on the grating.

3.4 TEST CHRONOLOGY

1) Install and pre-align grating
2) Pump out test chamber
3) Perform imaging tests
4) Perform efficiency tests along central row of grating
5) Obtain deep image for grating scatter test and evaluate

6) Return grating to best focus position
7) Backfill chamber, perform post-imaging test metrology and tilt/lower grating mount for top row efficiency tests
8) Pump out chamber
9) Perform efficiency tests along top row of grating
10) Backfill chamber and tilt/elevate grating mount for bottom row efficiency tests
11) Pump out chamber
12) Perform efficiency tests along bottom row of grating
13) Perform additional measurements for grating scatter if necessary
14) Backfill chamber and return grating to storage

4. SAFETY

4.1 OPERATOR SAFETY CONCERNS

4.1.1 High Voltage

All high voltage sources are clearly identified and properly grounded. These include the MCP detector operating voltages and the light source potentials.

4.1.2 N_2 Backfill Concerns

Because dry nitrogen gas (GN2) is used as a backfill and purge gas to limit water vapor exposure to the test optic and the detectors, care will be taken to monitor oxygen levels at all times. The vacuum chamber will not be entered until the O_2 partial pressure is above 20% as indicated on hand held O_2 monitors.

4.1.3 Lifting

No task will require lifting more than 15kg by any individual.

4.1.4 Crane Operations

These tests do not involve any use of the hoist or crane.

4.2 TEST ITEM SAFETY

4.2.1 Power Loss

The optics will be under purge at all times except for vacuum operations and installation. The purge will be independent of building electrical power. In the event of power loss to the building during vacuum operations, the vacuum chamber will automatically safe itself by shutting all valves and will require operator intervention to reopen any valves. It is possible to backfill the vacuum chamber with GN2 without electrical power.

4.2.2 Extreme Weather

No flight electrical equipment is being operated as a part of this test program, so there is no danger to flight hardware presented by lightening strike. Nevertheless, during extreme weather conditions testing will be suspended to avoid damage to GSE computers, power supplies, and motion controllers.

4.2.3 Contamination Control

4.2.3.1 Witness Coupons

Two coupons will be mounted with the grating for testing and test setup in close proximity to, and with the same field of view as the test optic whenever the test optic is removed from the storage container. The coupons will be stored with the test optic whenever the grating is in the storage container. The two coupons will be selected by BASD and prior to start of testing as described in BASD document COS-OPT-011.

4.2.3.2 Witness Plate

A 12.25” square witness plate will be tested for total mass and species identification by Ball Aerospace prior to optical testing. The witness plate will be installed in the chamber near to the test optic, and then will be retested after all grating tests are complete for each optic. In addition a small witness plate will be mounted in the vacuum chamber in place of the grating for initial chamber certification.

4.2.3.3 Bakeout/Qualification

All vacuum GSE other than fasteners and bare metal will be vacuum baked and TQCM certified in accordance with BASD document IN0090-111.

4.2.3.4 QCM Monitoring

Two quartz crystal microbalance contamination monitors will be installed in the vacuum chamber and operated continuously at –20C during vacuum operations. One will be placed above the table to view the entire setup, and one near the test grating with a view factor similar to the grating.

4.2.3.5 RGA Monitoring

A Residual Gas Analyzer is mounted on the chamber and will operate continuously to watch for hydrocarbon contamination as well as to monitor gas buildup from the flowing gas discharge lamp.

4.2.3.6 Thermal Monitoring

Five thermocouples will be installed in the test chamber. One will monitor the temperature of the delay line detector electronics and one will monitor the cold finger used to control the delay line detector electronics temperature. Additional thermocouples will be used to monitor the temperature of the grating manipulator motors and the grating mount.

4.2.3.7 Purge line Monitoring and Purge-box Monitoring

Prior to testing the purge lines into the Cleanroom and Controlled Stores were certified with a gas assay. The results for both were acceptable at 0.02mg/22.5 cu. Ft. See Ball Aerospace Analysis Report M&PI.R. Lab from G. K. Moller of 7/122/1999, work order 30408-99-270. Purge boxes 2 and 4 were surface tested with a solvent rinse prior to testing. These results were also acceptable at 0.08 mg/sq. ft. for Box 2, and 0.13 mg/sq. ft. for Box 4. See the same analysis report above.

GN2 flow to grating shipping containers in Controlled Stores will be checked daily and kept at 1 st. cu. ft./hour. GN2 flow to Cleanroom purge boxes and purge box humidity will be monitored daily. GN2 flow to purge boxes will be adjusted as necessary to maintain less than 1% relative humidity with doors closed. Logs of the above monitoring will be kept at CASA and reported as needed.

4.2.3.8 Clean room Monitoring

Prior to testing the Cleanroom and the adjacent gowning room (Anteroom) underwent a full service clean, and were re-certified as Class 100 on the tank-optics bench side and Class 1000 on the entry side and in the Anteroom.

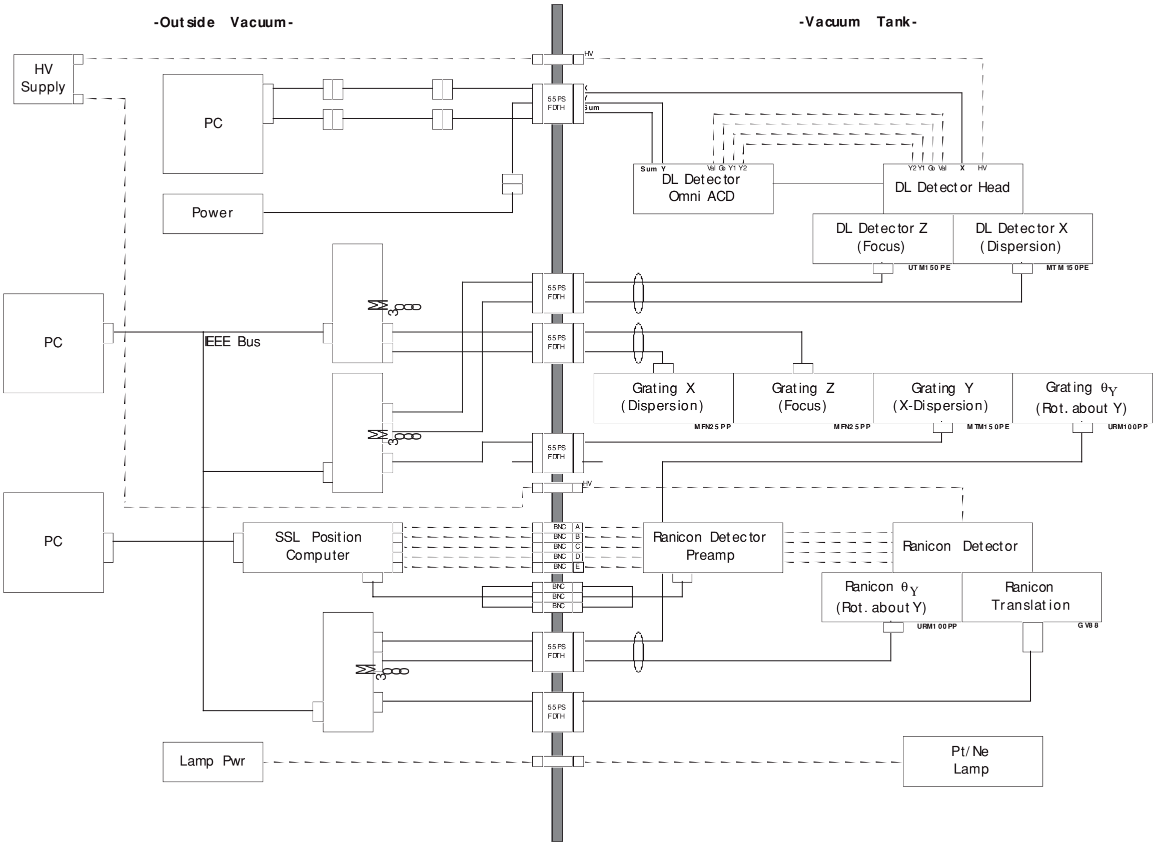
The Cleanroom and the Anteroom will be continuously monitored for particle count, humidity, and temperature. Particle count in both rooms will be maintained to Class 100 or Class 1000 levels as appropriate. Cleanroom humidity will be maintained at 20% relative humidity or less, and temperature will be kept generally constant, in a range from 60 degrees Fahrenheit to 75 degrees Fahrenheit, as needed for lab worker comfort. Logs of the above monitoring will be kept at CASA and reported as needed.

4.2.4 Grating Handling Procedures

The test optic is to be kept under purge in its serialized transportation container whenever possible. If the grating is in the cleanroom and neither mounted on the grating test assembly, or in its purged transportation container, the grating will be stored in a clean purge box. When the grating is not in either the transportation box or a purge box, it will be mounted in the grating test assembly. The grating will be covered with an aluminum handling cover whenever it is mounted in the grating test assembly and access to the front face is not required for testing or test setup. No mechanical operations will take place near the face of the grating when it is not covered. If the optic is to be kept outside of its storage container for more than 1 hour, or when it is unattended, a fully enclosed purge container will be placed over the grating and it will be maintained under GN2 purge.

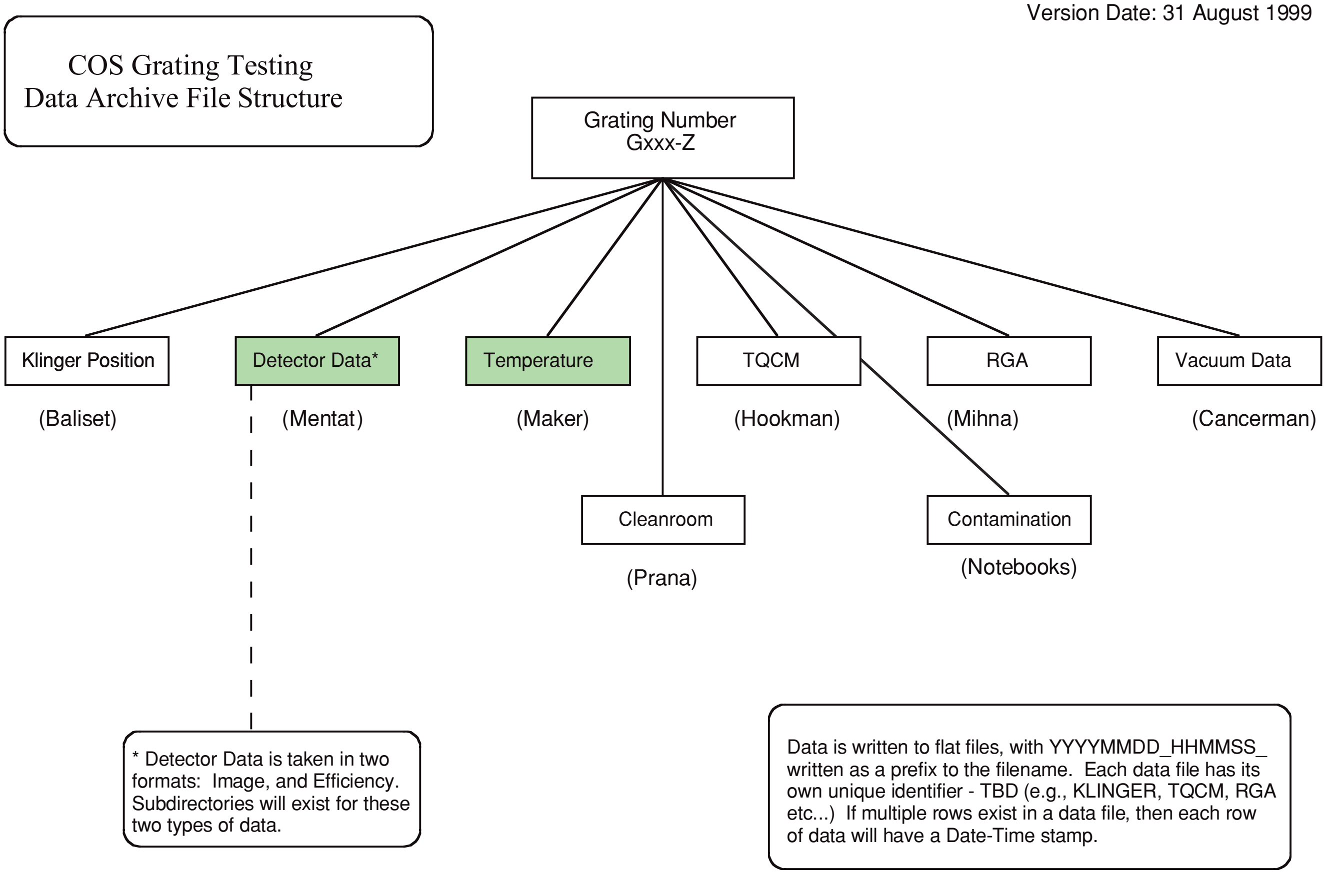
The test optic will not be removed from its storage container outside of a class 1000 cleanroom environment. The storage container will not be removed from its protective bagging outside of the anteroom to the CASA cleanroom.

Appendix A: Optical Test Wiring Diagram



Appendix B: COS Data Archiving Structure

Version Date: 31 August 1999



* Detector Data is taken in two formats: Image, and Efficiency. Subdirectories will exist for these two types of data.

Data is written to flat files, with YYYYMMDD_HHMMSS_ written as a prefix to the filename. Each data file has its own unique identifier - TBD (e.g., KLINGER, TQCM, RGA etc...) If multiple rows exist in a data file, then each row of data will have a Date-Time stamp.