M4 ellipsoidal mirror technical specification for the PEEM branch of the SM ID10-1 beamline

Technical Specification 6.8.76.6Rev0

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REVISION HISTORY

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1.0 INTRODUCTION

1.1 PURPOSE

This document contains the Technical Specifications for the M3 toroidal mirror for the PEEM branch of the SM 10ID-1 beamline at the Canadian Light Source.

1.2 SCOPE OF TECHNICAL SPECIFICATION

This technical specification establishes the requirements for the fabrication, inspection, testing and delivery of the x-ray mirror.

This specification includes, but is not limited to:

- Materials
- Detail drawings
- Fabrication requirements
- Quality Assurance and Testing

1.3 BACKGROUND

The Canadian Light Source is a national facility under construction on the University of Saskatchewan campus in Saskatoon, Saskatchewan. This facility is a 3rd generation synchrotron light (SR) source, which will produce a high intensity source of infrared, ultraviolet and x-ray radiation.

SpectroMicroscopy Beamline (SM) is a soft x-ray microscopy desiccated facility, which will provide intense soft x-ray light for Scanning Transmission X-ray Microscope and Photoelectron Emission Microscope. It will be built in the 10ID sector of the CLS main ring.

M4PEEM mirror is a refocusing optic in the PEEM branch of the SM beamline. It is placed 3m downstream of the PEEM exit slit and reflects the synchrotron radiation (SR) beam horizontally by 3 degree inboard (to the right as seen along the photon beam). The mirror orientation is vertical. The mirror optical surface is an ellipsoid of revolution, so it will provide 3x demagnified image of the exit slit at the location of the sample 1m downstream.

The power load absorbed by the mirror out of the EPU may be up to 10W, if the PGM is operated in zero order. Such power load does not required the internal water cooled design, but a moderate heat sink. So, the mirror is design as a monolithic block with cooling copper plate attached from below.

For alignment purpose the upper side of the mirror has a mirror-lake polished surface, parallel to the mirror central plane. The size and location of this surface is defined in the attached drawing.

The main optical surface area is 370 mm long by 20 mm wide. Surface figure errors and micro-roughness should not exceed the specified tolerances. The optical surface of the mirror shall be gold coated.

The mirror must be capable of being operated in an ultra high vacuum environment and subjected to soft x-ray radiation. It should withstand baking to 200^{o}C for 24 hours, and retain its shape and performance characteristic upon cooling to room temperature. The maximum operating temperature at the mirror surface is not to exceeded 30^{o}C.

Further background information can be found in the SM Preliminary Design Review CLS #6.2.76.10.

1.4 DEFINITIONS AND ABBREVIATIONS

CLS – Canadian Light Source

RMS - root mean square

SM- SpectroMicroscopy beamline.

SR – Synchrotron Radiation

EPU – Elliptically Polarized Undulator.

UHV - Ultra high vacuum

Zerodur® is a registered trademark glass ceramic of Schott Glaswerke, Mainz.

ULE is a registered trademark glass ceramic of Corning. The other material names specified on the drawing denote chemical elements.

2.0 MIRROR REQUREMENTS

2.1 GENERAL REQUREMENT AND DRAWINGS

2.1.1.The mirror substrate shall be manufactured, as specified in CLS DWG 10ID-1/ME/MIR4/0065219. Overall dimensions of the mirror substrate are approximately 380 mm (long) x 60 mm (wide) x 60 mm (thick)

2.1.2. The mirror substrate material shall be either ULE, or Zerodur, or fused quartz.

2.1.8. The finished mirror substrate shall be cleaned and all faces of the mirror shall be free of any dents, gouges or scratches.

2.1.9. The finished mirror shall be ultra high vacuum compatible. Refer to CLS Technical Specification, 8.7.33.1. Particular, residual materials that are not compatible with UHV environment shall not be present. UHV requirements are for low outgassing rates on the order of 10^{-7} Pa.liter/sec.mm^2 (10^{-11} Torr.liter/ sec.cm^2) and no detectable hydrocarbon.

2.1.10. The mirror shall withstand an in-vacuum baking of 200^{o}C for 24 hours and retain its shape and performance characteristic upon cooling to room temperature.

2.1.11. The contractor shall review the drawings and other documentations provided by the CLS for errors, and to inform the CLS of any discrepancies and errors. Any changes or corrections must be documented by the contractor as “marked drawing” changes and submitted to CLS for approval.

2.2 POLISHING AND COATING REQUIREMENTS

2.2.0.1. Two polished optical surfaces are required.

1. The flat surface ~45 mm wide by 60 mm long, as shown in CLS DWG 10ID-1/ME/MIR4/006065219, will be used in the mirror alignment procedure. The optical surface quality, of 40-30 or higher as defined by MIL-O-13830 specification is acceptable. The plane surface shall be parallel to the mirror central axis to within better than +/-0.5 mrad, and shall be measure to an accuracy of 0.1mrad.
2. The main active optical surface of the mirror is 370 mm long *20 mm wide. This is the primary optical surface, which sees the SR. Inside this area both mirror shape and mirror roughness shall meet the specified accuracy. The specifications on the drawing are for reference only.

2.2.0.2. An ‘optical chamfer’ is required around the surface of the mirror substrate to break the edge of the optical surface and prevent peeling of the optical coating. The polisher is free to polish a larger area as required.

2.2.0.3. Contractor shall specify for approval by the CLS any additional coating(s) (e.g. adherence layers) deemed necessary.

2.2.1 Mirror shape

2.2.1.1.The active optical surface of the mirror shall have an ellipsoidal shape, with the axis of revolution placed parallel to the mirror long edge. As for ellipsoidal mirror the sagittal radius is changing along the mirror, the mirror shall be oriented in a way, that smaller curvature (bigger sagittal radius shall be at the mirror side close to polished surface, used for mirror alignment procedure, where higher curvature side (smaller sagittal radius) will be closer to mirror identification string, as shown in 1/ME/MIR/00652.

2.2.1.2. The ellipsoidal surface geometry is illustrated by the Fig.1. The entrance arm (distance F1C) is 3m, the exit arm (distance CF2) is 1m and mirror grazing angle is 1.5 degree. These parameters lead to the following parameters of the ellipsoidal surface:
semi-major axis 2000mm
semi-minor axis 45.34mm
eccentricity 0.999743005.
2.2.1.3. The ellipsoidal surface shall be oriented in such a way, that the vector normal to the optical surface at the center of the mirror shall be perpendicular to the mirror substrate as well. The deviation from the mutual parallelism shall not exceed 0.5mrad. The

2.2.1.4. The mirror pole shall be at the center of the mirror substrate. The deviation from the center shall not exceed +/- 0.5mm.

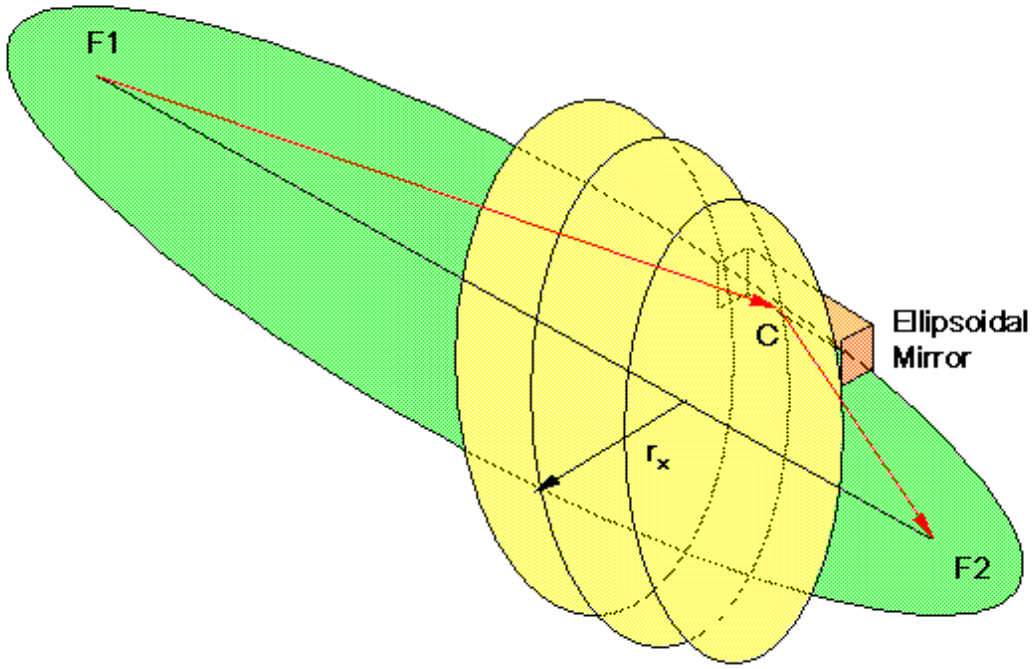

Fig.1. The mirror optical surface parameters and the ellipsoidal surface geometry. F1 and F2 are the focal poles of the ellipsoid and C- the central pole of the mirror. F1F2 is the axis of revolution. The green surface is the horizontal cut of the ellipsoidal surface, the yellow shaded are circles in vertical plane. Their radiuses are changing, depending on a position along the mirror. The ellipsoidal surface parameters are: the distance between F1 and C is 3m, the |CF2|- 1m, and F1CF2 angle is 177 degree.

2.2.2 Surface roughness

2.2.2.1.Surface roughness shall be defined as the root mean square (*RMS*) of the surface amplitudes with spatial wavelengths between 10 μm and 1 mm.

2.2.2.2.The average surface roughness measured shall not exceed 10.0 Å when measured with a 5X objective and 15 Å when measured with a 40X objective.

2.2.3 Slope error

2.2.3.1. Slope error shall be defined as the root mean square (*RMS*) of the slope of the mirror surface with spatial wavelengths between 1 mm and 370 mm.

2.2.3.2. The mirror surface deviation from ellipse in tangential direction (along the mirror long edge) shall not exceed 5 μrad.

2.2.3.3. The mirror surface deviation from circle in sagittal direction (along the mirror short sedge) of the mirror shall not exceed 40μrad.

2.2.4 Optical Coating

2.2.4.1. After polishing and cleaning an optical coating is to be applied to the mirror main optical surface. A large area can be coated, if necessary.

2.2.4.2. The coating material is Gold with purity higher that 99.99%.

2.2.4.3. Coating thickness is 500 angstrom +/-10% and shall be uniform over the entire active optical surface.

2.2.4.4. Any other adhesive layers or coatings, if needed from technological point of view, shall be consulted with and approved by CLS.

2.3 OTHER REQUIREMENTS

2.3.4. The machining process used shall be compatible with UHV applications. In particular

- No silicone or sulfur-based cutting fluids, lubricants or waxes, which may result in contamination, shall be used
- No operation causing contaminants to be embedded into the mirror substrate surface shall be permitted. Grinding under power with resin-bonded wheels, using rouge, emery cloth, crocus cloth, or similar abrasives are prohibited.
- The finished mirror substrate shall be cleaned and all side of the mirror shall be free of dents, gouges and scratches. Pure de-ionized water must sheet on all surfaces to verify the absence of surface contamination prior to preparation for polishing. Lint-free and talcum-free nylon gloves are to be worn when handling the mirror substrate after cleaning.

For other, refer to CLS Technical Specification, 8.7.33.1 for vacuum component cleaning specification.

2.4.1. The mirror shall be permanently marked with identifying letters plus number combination of the type SMxx engraved into the side face of the mirror at the location indicated in the drawing. The two digit number (xx) will be issued by the CLS at the time of contract award. The location and size of the identification number is defined in CLS DWG 10ID-1/ME/MIR4/0065219.

2.3.1 Shipping Container and Packing Requirements

2.3.1.1. The mirror shall be held firmly in one hermetically sealed container, referred to below as a primary mirror container. The container shall be evacuated by oil free pump and filled with dust free, dry nitrogen. No volatile adhesives or material, which may produce vapors, particular organics, shall be used for grating holding or as a part of the container. PMMA is prohibited. Teflon and aluminum, properly cleaned, are the preferable material for the mirror holder.

2.3.1.2. Primary mirror container shall be placed in another, outer box. The outer box must contain clean, non-chafing packing material which prohibits contact between the inner and outer boxes during shipment.

2.3.1.3. The outer box must be labeled sufficiently to alert any shipping personnel to the dangers of opening the box. Also, the outer box must be labeled in order to alert any shipping personnel to the dangers of dropping the box.

2.3.1.4. The packaging shall be sufficiently to survive a 48” drop, in any orientation, and prevent damage or degradation of the mirror performance. The inner and outer packaging must remain intact. Conformance to this requirement shall be confirmed by testing per ASTM D 5276, A2.2.2, Ten Drop Cycle (boxes). Packaging shall be of sufficient size to discourage inappropriate handling.

2.4 QUALITY ASSURANCE AND TEST REQUIREMENTS

3.3.0.2. The contractor shall submit with the proposal an Inspection and Test Plan for different stages of fabrication prior to the initiation of any procurement or fabrication activities and a list of methods and instruments that will be used for measurements of the surface figure and roughness. The CLS will review and approve the proponent’s Inspection and Test Plan.

3.3.0.1. Acceptance testing shall be performed on the finished mirror.

3.3.0.4. The CLS may conduct its own performance measurements using the same methods and one of the acceptable instruments as specified below for the minimum tests.

The following items are minimum requirements for inclusion in the acceptance tests.

2.4.1 Mutual orientation of the optical surface and mirror substrate

1. The orientation of ellipsoidal surface with respect to the mirror susbstrate shall be measured and properly documented. The sagittal radiuses at the locations, indicated in Fig.2 shall be measured with long trace profiler to reconfirm the elliptical shape of the mirror. The manufacture shall report other data, used to reconfirm the elliptical shape of the main optical surface, as well.

2.4.2 Surface figure slope error

1. The surface figure of the finished mirror substrate shall be measured with a laser system in geometry show in Fig.1. The nitrogen (337nm) laser shall be masked with 50 micron diameter pinhole, which provide diffraction limited illumination of the central part of the mirror, placed at 3m from pinhole. The mirror shall be masked to illuminate only the clear

aperture portion of the mirror. The detector with spatial resolution better that 1 micron shall be placed in the second focal spot of ellipsoidal mirror (1m from mirror) to record the focus spot and report to CLS. FWHM of the focusing spot smaller that 25micron in diameter is acceptable, and show, that the mirror slope error quality is as specified.

2.4.3 Surface roughness

1. The surface roughness of the mirror substrate shall be measured with a non-contacting optical profiler using a phase measuring interferometer technique. The instrument shall have objectives of approximately 5X and 40X magnification, capable of 20 μm and 5 μm camera resolution, respectively, and have at least 0.2 nm height resolution. Acceptable instruments are manufactured by Wyko, Zygo, and Micromap. Alternates need to be approved by the CLS.
2. The surface roughness shall be measured at the following locations (minimum requirement): eight test spots, formed as the crossed points between longitudinal and meridianal lines for slope error traces, as shown in Fig.1.
3. Surface roughness shall be measured two dimensionally as the root mean square of all surface height deviations from the average height measured in a rectangular sample area of size specified below at a certain step size specified below.
4. The surface roughness shall be determined at two different magnifications, camera resolution, and sampling sizes: (a) with 5X objective, 20 μm camera resolution and a sampling area of 2 *2 mm and (b) with 40X objective, 5 μm camera resolution and a sampling area of size 0.25 *0.25 mm.

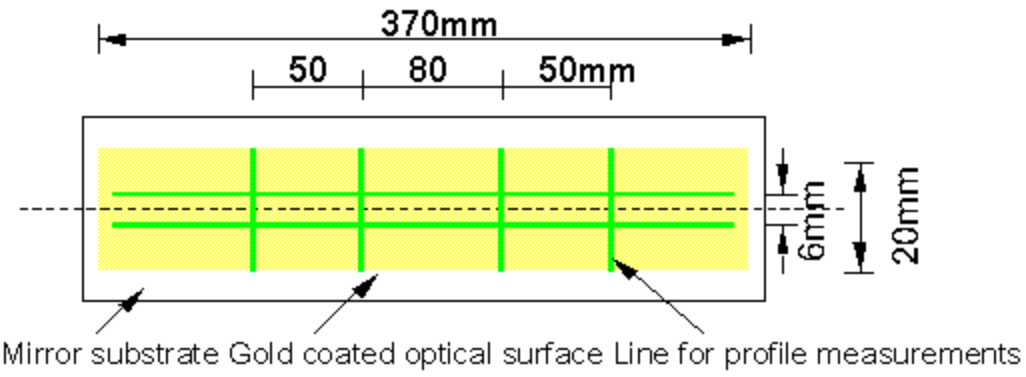

Fig.2. The location of the slope profile measurement lines. The figure is not scaled and for illustration purposes only.

3.0 APPENDIX.

M3PEEM toroidal mirror specification (summary).

Substrate: monolithic block
Material: Ultra Low Expansion (ULE), Zerodur, or fused silica.
Physical dimensions: approximately 380 mm long * 60mm wide * 60 mm thick
Clear aperture (main optical surface): 370 mm * 20 mm
Mirror shape: ellipsoid of revolution
source distance 3000mm, image distance 1000mm, total deflection angle 177 degrees.

semi-major axis 2000mm
semi-minor axis 45.34mm
eccentricity 0.999743005
Finished polishing (with hardened ad layer, if needed):
Slope errors (RMS):
Tangential (along the longer edge): <5 µrad
Saggital (along the shorter edge): <40 µrad
Microroughness: <10 Å