M3 toroidal mirror technical specification for the STXM branch of the SM ID10-1 beamline

Technical Specification 6.8.76.5Rev0

June 13, 2002

	Signature	Date
	Original on File – Signed by:	
Prepared by:	_____ K. Kaznacheyev	_____
Reviewed by:	_____ Adam Hitchcock	_____
Reviewed by:	_____ Tony Warwick	_____
Reviewed by:	_____ Jeremy Ransom	_____
Approved by:	_____ Emil Hallin	_____

Canadian Light Source Inc.
101 Perimeter Road
University of Saskatchewan
Saskatoon, Saskatchewan Canada S7N 0X4

REVISION HISTORY

Revision	*Date*	*Description*	*Author*
A	April 19, 2002	Draft	Kaznacheyev
0	June 13, 2002	Review completed, minor modification of the mirror testing/ verification procedure	Kaznacheyev

Table of Contents

1.0 INTRODUCTION

1.1 PURPOSE

This document contains the Technical Specifications for the M3 toroidal mirror for the STXM 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.

M3 STXMmirror is the forth optical element of the SM beamline. It is placed ~24.1m away from an Elliptically Polarized Undulator (EPU) and reflects the synchrotron radiation (SR) beam horizontally by 3 degree outboard (to the left as seen along the photon beam). The mirror orientation is vertical. The mirror has a toroidal shape of the optical surface, with the major radius plane (tangential plane) oriented horizontally. The sagittal (minor) radius is chosen so that the SR, dispersed by Plane Grating Monochromator (PGM) and collimated in vertical direction is focused on the exit slit 6.1 m downstream of the mirror. The tangential (major) radius is choused to provide a focusing condition in horizontal plane, so the electron beam, which is the source in this case, will be projected to the same exit slit.

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 axis. The size and location of this surface is defined in the attached drawing package.

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/MIR3/0065214. 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 single crystal silicon

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/MIR3/0065214, 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 plane to within better than +/-0.5 mrad, and shall be measure to an accuracy of 0.1mrad. The plane surface shall be

perpendicular to the surface tangential to the mirror pole (center) to within better than +/- 0.5mrad and shall be measure to an accuracy of 0.1 mrad.

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. This specification includes two technical options: (Option A) relaxed specification, and (Option B) tight requirements, both are specified below. 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 a toroidal shape, with the toroidal major plane along the mirror long edge, as shown in 10ID-1/ME/MIR3/0065214. The deviation of mirror substrate central plane from the toroidal major plane shall not exceed +/-0.5mrad and shall be measure to an accuracy of 0.1 mrad.

2.2.1.2.The toroidal major radius is R=367.1 m. The relative accuracy of the mirror radius is 3%, and is left to the manufacturer to determine the most appropriate value, based on their manufacturing and testing techniques. Once the mirror radius is chosen, it shall be reported to CLS for approval.

2.2.1.3. The toroidal minor radius is r=0.3141 m. The relative accuracy of the mirror radius is 1%, and is left to the manufacturer to determine the most appropriate value, based on their manufacturing and testing techniques. Once the mirror radius is chosen, it shall be reported to CLS for approval.

2.2.1.4. The mirror pole shall be at the center of the mirror substrate. The deviation from the center shall not exceed +/- 0.2mm in the sagittal (along short axis) direction and +/- 5mm in tangential (along long axis) direction.

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: Option A- 8.0 Å when measured with a 5X objective and 12 Å when measured with a 40X objective, Option B- 5.0 Å when measured with a 5X objective and 7.5 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 circle in tangential direction (along the middle of the reflecting surface parallel to the mirror long edge) shall not exceed: Option A- 5 μrad, Option B- 3 μrad.

2.2.3.3. The mirror surface deviation from circle in sagittal direction (along the middle of the reflecting surface parallel to the mirror short edge) of the mirror shall not exceed: Option A- 15 μrad, Option B- 10 μrad.

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 10ID-1/ME/MIR3/0065214.

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 Surface figure slope error

1. The surface figure of the finished mirror substrate shall be measured with a long trace profiler. Acceptable instruments are manufactured by Ocean Optics, Inc. Alternates need to be approved by the CLS.
2. Two profile traces of 350 mm length shall be measured along the centerline of the mirror, at a distance of 3 mm to either side of the centerline (minimum requirement). The step size or camera resolution shall be 1 mm.
3. Four profiles of 20 mm length shall be measured perpendicular to the centerline, as shown in Fig.1.
4. The slope error is acceptable if none of the average of the root mean square (*RMS*) of the slope errors determined separately for each profile does not exceed the specification value.

2.4.2 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.

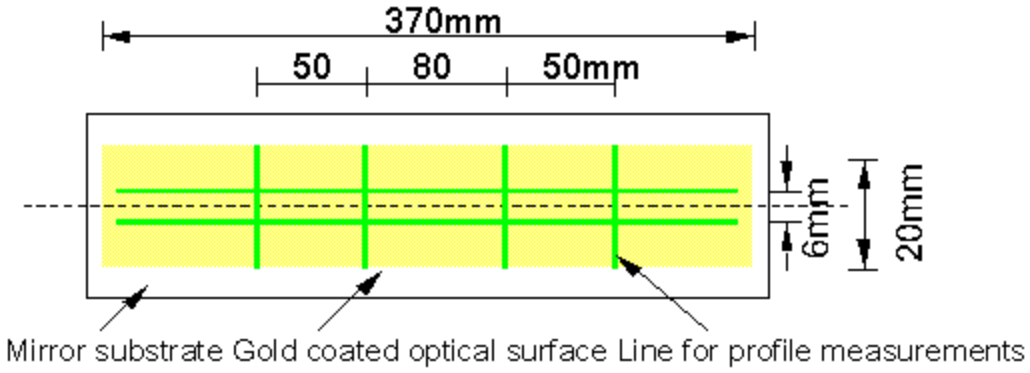

Fig.1. The location of the slope profile measurement lines. The figure is not scaled and for illustration purposes only.

3.0 APPENDIX.

M3STXM toroidal mirror specification (summary).

Substrate: monolithic block
Material: (A) ULE or (B) Zerodur or (C) optical grade single crystal silicon
Physical dimensions: approximately 380 mm long * 60mm wide * 60 mm thick
Clear aperture (main optical surface): 370 mm * 20 mm

Toroidal parameters:
Major radius (R): 367.1m +/- 0.5m
Minot radius (r): 314.1mm +/-1.6mm

Mutual accuracy of the mirror substrate to the toroidal optical figure match
Deviation of the toroidal pole from mirror center: <0.2mm in sagittal direction (along the short edge)
<5mm in tangential direction (along the long edge)
Deviation of the toroidal major plane from mirror central plane to be measured: <100μrad

Finished polishing:	Option A	Option B
Slope errors (RMS):		
Tangential (along the long edge):	5μrad	3μrad
Sagittal (along the short edge):	15μrad	10μrad
Microroughness (RMS):	0.8nm (8 Å)	0.5nm (4 Å)

Reflection coating: gold 50nm+/-5nm