

Six Mirrors and Three Variable Line Spaced Laminar Plane Gratings for The Variable Line Spacing Plane Grating Monochromator (VLS- PGM) Beamline

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1.0 INTRODUCTION

1.1 PURPOSE

This document specifies the requirements for 6 mirrors and 3 plane gratings to be fabricated, and installed on the floor at the Canadian Light Source (CLS). These components will be part of the variable line spacing plane grating monochromator (VLS-PGM) beamline.

1.2 SCOPE

The VLS-PGM beamline as specified by the user community requires high resolution and flux combined with a reasonably small beam size at the sample. This specification details the requirements for the fabrication, supply, and delivery of 6 beamline mirrors and 3 plane gratings. This specification includes but is not limited to:

- 3 spherical mirrors
- 3 plane gratings
- 1 plane mirror
- 2 toroidal refocusing mirrors
- fabrication, handling, and shipping guidelines
- delivery at CLS
- quality assurance and safety

1.3 BACKGROUND

The Canadian Light Source is a national facility under construction at the University of Saskatchewan campus in Saskatoon, Saskatchewan. This facility is a third generation synchrotron light source that will produce a high intensity source of infrared, visible, ultraviolet, and x-ray radiation. Based upon the needs of the Canadian synchrotron community, a low energy (5-250 eV) plane grating monochromator beamline is being constructed with a goal of being ready for operation when the facility is declared operational in early 2004.

2.0 GENERAL DESCRIPTION OF OPTICS

This section shall define and give a general description of the nine beamline optical components covered in this specification.

2.1 REFERENCE DOCUMENTS AND TABLES

Refer to the following supplied documents and drawings to aid in the definition of each optical component requiring fabrication. Please note that these supplied documents and tables also list components not covered in this specification. The specification covers specifically the M3 mirrors, the 3 plane gratings, the plane switchyard mirror, and the 2 toroidal refocusing mirrors.

- a) Ruben Reininger, "Technical Preliminary Design Report For the Variable Line Spacing-Plane Grating Monochromator (VLS-PGM) Beamline for the Canadian Light Source, July 16, 2001. ^[1].
- b) Table 1:Optical components and design parameters of the beamline. Units are in mm and degree. Positions are relative to the center of the insertion device. Rotations are relative to previous element (SHADOW nomenclature) ^[2].
- c) Concept drawing of standard substrate shape including base steps/ledges for mating substrates to mirror mounts ^[3].

2.2 LOW ENERGY MIRROR (M3L)

This spherical mirror with a grazing angle of incidence of 15 degrees shall be housed within the monochromator chamber and work in conjunction with the low energy grating (LEG).

2.3 MEDIUM ENERGY MIRROR (M3M)

This spherical mirror with a grazing angle of incidence of 12 degrees shall be housed within the monochromator chamber and work in conjunction with the medium energy grating (MEG).

2.4 HIGH ENERGY MIRROR (M3H)

This spherical mirror with a grazing angle of incidence of 4.5 degrees shall be housed within the monochromator chamber and work in conjunction with the high energy grating (HEG).

2.5 LOW ENERGY GRATING (LEG)

This variable line spaced plane grating with of grazing angle of incidence of 1-15 degrees shall be housed within the monochromator chamber and work in conjunction with the low energy mirror (M3L).

2.6 MEDIUM ENERGY GRATING (MEG)

This variable line spaced plane grating with of grazing angle of incidence of 5-12 degrees shall be housed within the monochromator chamber and work in conjunction with the medium energy mirror (M3M).

2.7 HIGH ENERGY GRATING (HEG)

This variable line spaced plane grating with of grazing angle of incidence of 1.7-4.5 degrees shall be housed within the monochromator chamber and work in conjunction with the high energy mirror (M3H).

2.8 SWITCHYARD MIRROR (M4)

This plane mirror with a grazing angle of incidence of 4.5 degrees is housed in a chamber downstream of the monochromator chamber. When in place deflects the beam down a second endstation branch.

2.9 REFOCUSING MIRROR A (M5)

This toroidal mirror with a grazing angle of incidence of 4 degrees focuses the beam into one of the endstation areas.

2.10 REFOCUSING MIRROR B (M6)

This toroidal mirror with a grazing angle of incidence of 4.5 degrees focuses the beam into the second of the endstation areas.

3.0 GLOBAL REQUIREMENTS

- 3.1 All fabrication of these optical components shall be consistent with operation of these components in ultra-high vacuum (UHV) conditions.
- 3.2 Since all three grating are to have variable line spacing, a mark shall be placed upon the side of each grating substrate to denote upon which side of the grating the higher line density is to be found.
- 3.3 The grating parameters specified are for rotation of the gratings around the inside order (+1).
- 3.4 Detailed design and construction of the vacuum chambers, including the mounts, holders, cooling, and movement mechanisms for gratings and mirrors will be undertaken by the successful bidder in response to a different RFP. The proponent supplying the chamber shall be given the top priority of designing the mounts, holders, cooling, and movement mechanisms, for the mirrors and gratings in this specification. All this information, including final dimensions (such as required substrate thickness) of all these optics (including for example any grooves required in the side of the optic substrates for mating optics and their mounts), will be provided by the CLS as soon as it is complete so as to maximize available time for completion of the optical components.
- 3.5 Finite element analysis (FEA) is being performed on the M3 mirrors as well as the plane gratings. This analysis when completed by Instrument Design Technology Ltd., shall be incorporated into the detailed design of the mounts and cooling for these optics. Based upon preliminary estimates of power density, it is anticipated that none of these components shall require internal cooling, and side contact cooling shall be more than sufficient.
- 3.6 All non-optical surfaces must be ground to within 0.025 mm
- 3.7 Unless otherwise shown below, all substrate dimensions should have a tolerance of plus or minus 0.3 mm.
- 3.8 Machining on the sides of all substrates shall conform to the conceptual diagram for machining required to mate substrate to optical mounts^[3]. In each case this machining consists of two steps/ledges, one along each side of the long axis of the substrate at the base. This step shall be 10 mm in height and 10 mm in width.
- 3.9 All widths/heights of substrates as specified in the document shall refer to the width/height of the optic at the optical surface and NOT the width/height at the base of the substrate where the steps/ledges are found.

4.0 LOW ENERGY MIRROR (M3L) REQUIREMENTS

- 4.1 The mirror figure shall be spherical with a radius of 15465 mm to within 0.1% or better.
- 4.2 The grazing angle of incidence for this mirror shall be 15 degrees.
- 4.3 The mirror substrate shall be Si.
- 4.4 The reflective surface of this mirror shall be Si.
- 4.5 The optical length of this mirror shall be 50 mm.
- 4.6 The optical width of this mirror shall be 20 mm.
- 4.7 Substrate thickness shall be 40 mm
- 4.8 The RMS Tangential figure error shall be 0.1 arcsec or better.
- 4.9 The RMS Sagittal figure error shall be 5 arcsec or better.
- 4.10 RMS surface roughness of the mirror shall be 0.7 nm or better.

5.0 MEDIUM ENERGY MIRROR (M3M) REQUIREMENT

- 5.1 The mirror figure shall be spherical with a radius of 19240 mm to within 0.1% or better.
- 5.2 The grazing angle of incidence for this mirror shall be 12 degrees.
- 5.3 The mirror substrate shall be Si.
- 5.4 The reflective surface of this mirror shall be graphite (density greater than or equal to 2.2 grams per cubic centimeter)
- 5.5 The optical length of this mirror shall be 55 mm.
- 5.6 The optical width of this mirror shall be 20 mm.
- 5.7 The RMS Tangential figure error shall be 0.1 arcsec or better.
- 5.8 The RMS Sagittal figure error shall be 5 arcsec or better.
- 5.9 RMS surface roughness of the mirror shall be 0.5 nm or better before coating. After coating the RMS roughness should be better than 1 nm.

6.0 HIGH ENERGY MIRROR (M3H) REQUIREMENTS

- 6.1 The mirror figure shall be spherical with a radius of 50721 mm to within 0.1% or better.
- 6.2 The grazing angle of incidence for this mirror shall be 4.5 degrees.
- 6.3 The mirror substrate shall be Si.
- 6.4 The reflective surface of this mirror shall be graphite (density greater than or equal to 2.2 grams per cubic centimeter).
- 6.5 The optical length of this mirror shall be 100 mm.
- 6.6 The optical width of this mirror shall be 20 mm.

- 6.7 The RMS Tangential figure error shall be 0.1 arcsec or better.
- 6.8 The RMS Sagittal figure error shall be 5 arcsec or better.
- 6.9 RMS surface roughness of the mirror shall be 0.5 nm or better before coating. After coating, the RMS roughness should be better than 1 nm.

7.0 LOW ENERGY GRATING (LEG) REQUIREMENTS

- 7.1 The grating figure shall be planar ($R > 5 \times 10^5$ m).
- 7.2 The grazing angle of incidence for this grating shall be 1-15 degrees.
- 7.3 The grating substrate shall be Si.
- 7.4 The reflective surface of this grating shall be Si.
- 7.5 The length of the grating shall be 96 mm.
- 7.6 The width of this grating shall be 25 mm.
- 7.7 The RMS Tangential figure error shall be 0.1 arcsec or better.
- 7.8 The RMS Sagittal figure error shall be 5 arcsec or better.
- 7.9 RMS surface roughness of the grating shall be 0.7 nm or better.
- 7.10 Line density at the grating center shall be 500 lines / mm.
- 7.11 The grating shall be variably line spaced. The equations detailing the quadratic variation of the groove spacing were taken from the article by Amemiya *et. al.*^[4]. The parameters describing the grating line space variation, are defined by the expression

$$\sigma(w) = 1 / (k (1 + 2b_2w + 3b_3w^2))$$

- 7.12 b_2 shall be $2.4028 \times 10^{-4} \text{ mm}^{-1}$ plus or minus 0.1% or less
- 7.13 b_3 shall be $5.5 \times 10^{-8} \text{ mm}^{-2}$ plus or minus 50 % or less.
- 7.14 The grating shall be laminar in profile. If the profile will be trapezoidal, expected parameters should be submitted for approval with the bid
- 7.15 The groove depth shall be 60 nm plus or minus 5 nm.
- 7.16 The ratio of groove to period shall be 0.65 plus or minus 0.05.
- 7.17 The grating center ($w \neq 0$) should be aligned within ± 0.1 mm with respect to half the substrate length.
- 7.18 The ruling must be perpendicular to the length of the grating with plus or minus 0.05 degrees or better.

8.0 MEDIUM ENERGY GRATING (MEG) REQUIREMENTS

- 8.1 The grating figure shall be planar ($R > 5 \times 10^5$ m).
- 8.2 The grating figure shall be planar.
- 8.3 The grazing angle of incidence for this grating shall be 5-12 degrees.
- 8.4 The grating substrate shall be Si.

- 8.5 The reflective surface of this grating shall be graphite (density $\geq 2.2 \text{ gr/cm}^3$).
- 8.6 The length of this grating shall be 86 mm.
- 8.7 The width of this grating shall be 25 mm.
- 8.8 The RMS Tangential figure error shall be 0.1 arcsec or better.
- 8.9 The RMS Sagittal figure error shall be 5 arcsec or better.
- 8.10 RMS surface roughness of the mirror shall be 0.5 nm or better before coating. After the coating the RMS roughness should be better than 1 nm.
- 8.11 Line density at the grating center shall be 1000 lines / mm.
- 8.12 The grating shall be variably line spaced. The equations detailing the quadratic variation of the groove spacing were taken from the article by Amemiya *et. al.*^[4]. The parameters describing the grating line space variation, are defined by the expression
- $$? (w) = 1 / (k (1 + 2b_2w + 3b_3w^2))$$
- 8.13 b_2 shall be $2.440 \times 10^{-4} \text{ mm}^{-1} \pm <0,1 \%$.
- 8.14 b_3 shall be $5.7 \times 10^{-8} \text{ mm}^{-2} \pm <50 \%$.
- 8.15 The grating shall be laminar in profile. If the profile will be trapezoidal, expected parameters should be submitted for approval with the bid.
- 8.16 The groove depth shall be $23 \pm 2 \text{ nm}$.
- 8.17 The ratio of groove to period shall be 0.60 ± 0.05
- 8.18 The grating center ($w \neq 0$) should be aligned within $\pm 0.1 \text{ mm}$ with respect to half the substrate length.
- 8.19 The ruling must be perpendicular to the length of the grating with plus or minus 0.05 degrees or better.

9.0 HIGH ENERGY GRATING (MEG) REQUIREMENTS

- 9.1 The grating figure shall be planar ($R > 5 \times 10^5 \text{ m}$).
- 9.2 The grazing angle of incidence for this grating shall be 1.7-4.5 degrees.
- 9.3 The grating substrate shall be Si.
- 9.4 The reflective surface of this grating shall be graphite (density $\geq 2.2 \text{ gr/cm}^3$).
- 9.5 The length of this grating shall be 126 mm.
- 9.6 The width of this grating shall be 25 mm.
- 9.7 The RMS Tangential figure error shall be 0.1 arcsec or better.
- 9.8 The RMS Sagittal figure error shall be 5 arcsec or better.
- 9.9 RMS surface roughness of the mirror shall be 0.5 nm or better before coating. After the coating the RMS roughness should be better than 1 nm.
- 9.10 Line density at the grating center shall be 600 lines / mm.

- 9.11 The grating shall be variably line spaced. The equations detailing the quadratic variation of the groove spacing were taken from the article by Amemiya *et. al.*^[4]. The parameters describing the grating line space variation, are defined by the expression
- $$\sigma(w) = 1 / (k (1 + 2b_2w + 3b_3w^2))$$
- 9.12 b_2 shall be $2.49064 \times 10^{-4} \text{ mm}^{-1} \pm <0,1 \%$.
- 9.13 b_3 shall be $6.1 \times 10^{-8} \text{ mm}^{-2} \pm <30 \%$.
- 9.14 The grating shall be laminar in profile. If the profile will be trapezoidal, expected parameters should be submitted for approval with the bid.
- 9.15 The groove depth shall be $20 \pm 2 \text{ nm}$.
- 9.16 The ratio of groove to period shall be 0.70 ± 0.05 .
- 9.17 The gratings centers ($w=0$) should be aligned within $\pm 0.1 \text{ mm}$ with respect to half the substrate length.
- 9.18 The ruling must be perpendicular to the length of the grating with plus or minus 0.05 degrees or better.

10.0 M4 SWITCHYARD MIRROR REQUIREMENTS

- 10.1 The mirror figure shall be planar ($R > 2 \times 10^5 \text{ m}$).
- 10.2 The grazing angle of incidence for this mirror shall be 4.5 degrees.
- 10.3 The mirror substrate shall be zerodur or fused silica.
- 10.4 The reflective surface of this mirror shall be graphite (density $\geq 2.2 \text{ gr/cm}^3$).
- 10.5 The optical length of this mirror shall be 160 mm.
- 10.6 The optical height of this mirror shall be 25 mm.
- 10.7 The RMS Tangential figure error shall be 2 arcsec or better.
- 10.8 The RMS Sagittal figure error shall be 1 arcsec or better.
- 10.9 RMS surface roughness of the mirror shall be 0.5 nm or better before coating. After the coating the RMS roughness should be better than 1 nm.

11.0 REFOCUSING MIRROR A (M5) SPECIFIC REQUIREMENTS

- 11.1 The mirror figure shall be toroidal. The Tangential radius shall be 61 m to within 1%. The Sagittal radius shall be 0.140 m to within 1%.
- 11.2 The grazing angle of incidence for this mirror shall be 4.0 degrees.
- 11.3 The mirror substrate shall be zerodur or fused silica.
- 11.4 The reflective surface of this mirror shall be graphite (density $\geq 2.2 \text{ gr/cm}^3$).
- 11.5 The optical length of this mirror shall be 180 mm.
- 11.6 The optical height of this mirror shall be 25 mm.
- 11.7 The RMS Tangential figure error shall be 2 arcsec or better.

- 11.8 The RMS Sagittal figure error shall be 2 arcsec or better.
- 11.9 RMS surface roughness of the mirror shall be 1 nm or better before coating. After the coating the RMS roughness should be better than 1 nm.

12.0 REFOCUSING MIRROR B (M6) SPECIFIC REQUIREMENTS

- 12.1 The mirror figure shall be toroidal. The Tangential radius shall be 40.2 m to within 1%. The Sagittal radius shall be 0.118 m to within 1%.
- 12.2 The grazing angle of incidence for this mirror shall be 4.5 degrees.
- 12.3 The mirror substrate shall be zerodur or fused silica.
- 12.4 The reflective surface of this mirror shall be graphite (density $\geq 2.2 \text{ gr/cm}^3$). How thick?
- 12.5 The optical length of this mirror shall be 160 mm.
- 12.6 The optical height of this mirror shall be 20 mm.
- 12.7 The RMS Tangential figure error shall be 2 arcsec or better.
- 12.8 The RMS Sagittal figure error shall be 2 arcsec or better.
- 12.9 RMS surface roughness of the mirror shall be 0.5 nm or better before coating. After the coating the roughness should be better than 1 nm.

13.0 SAFETY, ENVIRONMENTAL, AND RELIABILITY

- 13.1 The vacuum chambers shall be capable of operation in an ambient temperature range of 10 to 40 degrees C. The normal ambient temperature on the experimental floor is 21 degrees C. The expected temperature stability of the building will be 1 degree C during normal operation.
- 13.2 The components shall be able to withstand a relative humidity range of 0% to 95%. The expected relative humidity limits under operation are from 25% during the winter months and a maximum of 50% during the summer months. The expected relative humidity range for components under storage will be the same as previously mentioned.

14.0 QUALITY ASSURANCE AND TESTING

- 14.1 The proponent shall maintain and apply a quality assurance program compliant with ISO-9001 for the design, manufacture, procurement, and testing.
- 14.2 The first order efficiency of the gratings shall be greater than or equal to 80% of the theoretical value as specified by the grating parameters.

15.0 APPLICABLE CODES, STANDARDS, AND PROCEDURES

This work shall meet the following standards. The issue of any standard shall be the issue in effect as of the date of request for tender. Any conflicts between this

specification and the referenced documents shall be brought to the attention of the CLS in writing for resolution before any related action is to be taken by the proponent.

American Welding Society (AWS)
American Society for Testing and Material (ASTM)
American Society of Mechanical Engineers, Boiler and Pressure Vessel Code (ASME-BPVC)
American National Standards Institute (ANSI)
International Standards Organization (ISO)
Canadian Light Source Vacuum Component Cleaning Technical Procedure ^[5]
Canadian Light Source Vacuum Component Leak Test Technical Procedure ^[6]

16.0 OTHER REQUIREMENTS

- 16.1 All components of each section shall be completed, and delivered, at CLS as soon as possible. In the case of the M3 mirrors and gratings, these components shall be delivered in paired sets corresponding to low, medium, and high energy operation of the beamline.
- 16.2 Packaging to be used during shipping of components shall ensure protection of the components from water, dust, oil, and vibration during shipping. The packaging should be hermetically sealed. Jarring or impact sensors shall be attached to package for shipping.
- 16.3 Components shall be held securely in the shipping containers to prevent chafing or scratching that could damage the components and / or generate contaminants.
- 16.4 The shipping containers shall be properly labeled in English to ensure proper care during shipment.
- 16.5 All documentation to the CLS shall be in English and conform to CLS document specifications ^[7].
- 16.6 Documentation supplied to the CLS shall be provided in hard copy in triplicate plus one electronic copy if available. All drawings shall be supplied in AutoCAD format. All drawings and other documentation should also be appropriately labeled, numbered, and include a revision history.
- 16.7 Documentation detailing the correct methods of handling and cleaning these optical components shall be included.

17.0 REFERENCES

- 1 Ruben Reininger, "Technical Preliminary Design Report For the Variable Line Spacing-Plane Grating Monochromator (VLS-PGM) Beamline for the Canadian Light Source, July 16, 2001.
- 2 Table 1:Optical components and design parameters of the beamline. Units are in mm and degree. Positions are relative to the center of the insertion device. Rotations are relative to previous element (SHADOW nomenclature).
- 3 Concept drawing of standard substrate shape including base steps/ledges for mating substrates to mirror mounts.

- 4 K. Amemiya, Y. Kitajima, T. Ohta et al., J. Synchrotron Rad. 3, 282 (1996).
- 5 Canadian Light Source Vacuum Component Cleaning Technical Procedure, 8.7.33.1, September 13, 2000.
- 6 Canadian Light Source Vacuum Component Leak Test Technical Procedure, 8.7.33.2, September 13, 2000.
- 7 D.S. Lowe. "CLS Document Specification", 0.4.1.1 Rev. 2 14 Dec 2000

RFP SELECTION CRITERIA

a)	Technical -understanding the scope of the work -fabrication -ability to meet minimum functional and performance requirements -performance ability -quality and duration of proposed warranty periods -proposed delivery if different from stated	35%	
b)	Cost -proposal pricing -cost saving proposals -value added benefits and incentives -proposed payment structure	35%	
c)	Proponent Qualifications -corporation structure and ownership -demonstrated ability to satisfy the University requirements -relevant experience, competence, and reliability in handling similar projects, based upon references -international scientific reputation of company	20%	
d)	Economic Benefits and Incentives Program -national, regional, and local benefits	5%	
e)	Any other factors the CLS may consider appropriate	5%	
		100 %	

Note: All bids are to be submitted in Canadian dollars.

SCOPE OF WORK

The Proponent shall provide all material, labour, equipment, and services required to complete the Work as set out in the RFP. The Work shall be that which is called for in specifications and drawings. The Work shall include but is not limited to the following:

1. Supply and complete the planning, design, and engineering to carry out the Work.
2. Plan and implement the procurement of materials, equipment, and services to carry out the work.
3. Provide and implement a Quality Assurance and Control Program (QA/QC) for the Work. The QA/QC program to include the testing, certifications, and inspections specified within this RFP.
4. Carry out, document, and distribute the results of testing, certifications, and inspections as specified within this RFP.
5. Provide documentation as specified within this RFP.
6. Provide the components specified in this document including all nine optical elements.
7. Provide all measurement and testing as defined or required to perform the work. Provide copies of all results to the CLS.
8. Provide packaging and transportation of finished product to designated CLS site.

PROPOSAL COST SUMMARY FORM

Proponents shall provide their proposal cost summary using the following format in Canadian dollars:

Six Mirrors and Three Variable Line Spaced Laminar Plane Gratings for The Variable Line Spacing Plane Grating Monochromator (VLS-PGM) Beamline

Item#	Description	Quantity	Unit Rate	Total
1	Fabrication M3L	1		
2	Fabrication M3M	1		
3	Fabrication M3H	1		
4	Fabrication LEG	1		
5	Fabrication MEG	1		
6	Fabrication HEG	1		
7	Fabrication M4	1		
8	Fabrication M5	1		
9	Fabrication M6	1		
10	Factory Testing	1		
11	Subtotal			
12	PST			
13	GST			
14	Duties			
15	Shipping			
16	Subtotal			
17	Total			

SPECIAL REQUIREMENTS TO BE INCLUDED IN RFP

1. Proponent shall provide examples of previous work that demonstrates the proponent's capacity to fabricate beamline components with similar performance to the components specified in this document.
2. Provide names and phone numbers of two references to whom the proponent has supplied synchrotron beamline components that may be contacted by the CLS.
3. Proponent shall provide a list of any exceptions or alterations to statements, parameters, and tolerances in this document and attached drawings.
4. CLS reserves the right to visit the proponent's facility before awarding a contract.
5. CLS reserves the right to inspect components and facilities during fabrication.
6. The proponent shall propose a schedule with the following milestones:
 - start
 - completion of substrates
 - completion of optical figures
 - completion of mirrors
 - completion of grating ruling
 - factory tests
 - shipment to CLS

The proponent shall also propose a schedule of site visits by representatives of the CLS. It is suggested that these visits occur at approximately the following milestones:

- factory tests
 - just before shipment to the CLS
7. All parameters of the optics specified in this document, including but not necessarily limited to: figure errors, surface roughness, ruling density, variable line spacing parameters, groove depth, and groove to period ratio, shall be measured and submitted to CLS prior to final approval of any optic. The methods used to measure these parameters shall be described in the bid statement.