

# CMCF 08ID-1 Preliminary Design Report

Design Note – 6.2.77.2 Rev. 0

April 3, 2002

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## 1.0 INTRODUCTION

This is a Preliminary Design Report for the CMCF 08ID-1 Protein Crystallography beamline. It includes specifications for all beamline components and design drawings for most of them.

### 1.1 PURPOSE

To build a state-of-the-art beamline for protein crystallography, capable of running in the automatic mode Multiple-Wavelength Anomalous Dispersion (MAD) experiments as well as collecting data at high resolution.

### 1.2 SCOPE

This document describes in detail the design of the 08ID-1 beamline including optics, vacuum system and beam transport, utilities, endstation instrumentation, Beamline Process Flow Diagrams, and Process and Instrumentation Diagrams.

### 1.3 BACKGROUND

In 1999 the community of Canadian crystallographers submitted to the Canadian Light Source a proposal to build a protein crystallography (PX) beamline. The beamline, together with associated staff, would be called the Canadian Macromolecular Crystallography Facility (CMCF).

The CMCF researchers are primarily focused on macromolecular crystallographic studies. Their research includes new structure determinations, high-resolution structural analyses, drug design, protein engineering, site-directed mutagenesis projects, and a growing emphasis on genomics. To successfully pursue their research interests they require structural research tools significantly more powerful than the laboratory tools available to them in their home institutions. They require the extraordinarily high x-ray brilliance and beam properties available at the CLS to study small crystals ( $>20 \text{ \AA}$ ) and crystals with large cell dimensions ( $<1000 \text{ \AA}$ ). They also require the ease and precision of X-ray energy tuning available at the CLS in order to use the powerful tool of Multiple-Wavelength Anomalous Dispersion (MAD) phasing for structural determinations of large molecular systems. These imply that the beamline has to have superior optics with inherent focusing capability in the horizontal and vertical position to get the very small beam size at the sample. Moreover, the beamline has to be as long as possible to get small crossfire at the sample. Also, because of the large number of CMCF participants, each with large numbers of samples to be studied, they require the high level of productivity that an intense source such as CLS provides when coupled with a highly efficient and productive beamline design.

The requirements specified in the Conceptual Design for the Protein Crystallography Beamline are essential to carry out the scientific program of the CMCF community. They are (described in CMCF 08ID-1 Beamline – Technical Specifications (6.8.77.1) [1] as follows:

Energy range	6.5 – 18.0 keV
Energy resolution $\Delta E/E$	$10^{-4}$
Flux	$10^{13}$ ph/s/0.1%bw
Focal size at the sample	160 $\mu\text{m}$ x 50 $\mu\text{m}$ FWHM (horizontal x vertical)
Crossfire on the sample	< 1 mrad

The search for a design suitable for the CMCF needs indicated that the SBC 19-ID beamline at the APS would be a good choice. It provides an extremely high-flux density ( $3.6 \times 10^{15}$  ph/s/mm<sup>2</sup>) in a very small focus (80  $\mu\text{m}$  x 40  $\mu\text{m}$  FWHM, horizontal x vertical) at the sample ( $1.15 \times 10^{13}$  ph/s) and the spot size at the detector is well matched to state-of-the-art CCD-based area detectors [2]. The experience of the SBC 19-ID beamline clearly demonstrated that its design (enclosures, optics, and instrumentation) meets the needs of the CMCF research community.

The design is very versatile as evidenced by the selection of this design by BioCAT for their undulator beamline dedicated to biological EXAFS and small angle diffraction/scattering. The optical design is based on the design of beamline X9B at the National Synchrotron Light Source which besides being one of the most productive beamlines for biological EXAFS is now also very successfully used for macromolecular crystallography. X9B, while delivering one of the highest flux densities from a bending magnet at the NSLS, has proven over the last 10 years to be very robust and reliable with extremely low down time due to equipment failure. Experience with the undulator beamlines of the SBC as well as BioCAT indicate the same high level of robustness and reliability.

Although the SBC beamlines were designed more than seven years ago, we have found that the basic designs are still optimal. The optics system provides X-ray beams with properties near the theoretically obtainable limits. Small improvements will be achieved through the modification of the monochromator design to achieve better tracking stability and incorporation of a new cryo-crystal that was designed and implemented at IMCA-CAT and MR-CAT [3], and also implemented at Bio-CAT.

The major CMCF improvements to the SBC design will be in the operational and user area: user-friendly control and data acquisition software, incorporation of new technologies in robotic sample placement and alignment, and other details of the end station instrumentation. The speed of data acquisition (number of data sets per unit time) of the ID beamline will be increased by a factor of 3-5 by implementing a robotics system for remote sample placement and alignment, which should lead to a proportional increase in scientific throughput. Further increases in productivity are envisioned through improved control and data acquisition systems and eventual implementation of a "telepresence" capability by which researchers will be able to monitor their experiments from their home bases using high-speed network connections.

The concept for the CMCF and SBC beamline has been to develop a coherent design for the whole beamline from front to rear - optics and their placement, sample stage, and detector, all matched and forming one unit, optimized for how macromolecular crystallography is done best with an undulator source.

Choosing the 19-ID beamline design will eliminate substantial engineering at the CLS. The SBC-CAT beamline was designed and built by a very experienced designer (Dr. Gerold Rosenbaum) in collaboration with the Larry Rock Automation Associates.

Presently Dr. Rosenbaum is a Project Director at the South East Regional Collaborative Access Team (SER-CAT) where he is building the 22-ID and 22-BM beamlines and will be our consultant during the design, assembly and commissioning stage. Major parts of this design are also being implemented at the 4.2.2 beamline at ALS.

## 1.4 DEFINITIONS AND ABBREVIATIONS

SGU - Small Gap In-vacuum Undulator

08-ID-A - FOE (First Optical Enclosure)

08-ID-B - White-beam transport (WBT)

08-ID-C - Hutch with all optical components

08-ID-D - Experimental hutch

DI – Deionized water

PLC – Programmable Logical Controller

PSS - Personnel Safety System

EPS - Equipment Protection System

ULE™ – (Ultra Low Expansion) is a registered trademark glass ceramic of Corning

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

## 1.5 CLS RING SPECIFICATIONS

	Start of operation (2003)	After 1-2 years of operation	Long-term goals
Energy (GeV)	2.9	2.9	2.9
Current (mA)	100	200	500
Time structure	multi-bunch	multi-bunch	multi-bunch or single-bunch
Effective Horizontal Emittance (nm×rad)	<30	<20	18.1
Energy Spread			0.111 %
Lifetime (h)	> 4	> 6	> 10 (or Top-up)
<i>x-y</i> Coupling (minimum)	<10%	<1%	< 0.2%
$\gamma$	5675.3	5675.3	5675.3
$\lambda_c$	1.6378 Å	1.6378 Å	1.6378 Å
$E_c$	7.572 keV	7.572 keV	7.572 keV
Circumference	170.88 m	170.88 m	170.88 m
Periodicity	12	12	12
Straights Length:	5.2 m	5.2 m	5.2 m
$\beta_x, \beta_z, v_x$	8.5 m, 4.6 m, 0.15 m	8.5 m, 4.6 m, 0.15 m	8.5 m, 4.6 m, 0.15 m
Dipole Field	1.354 T	1.354 T	1.354 T

## 2.0 PORT ALLOCATION

The beamline allocation with respect to the whole ring of the CLS as shown in Figure 1 is described in the Photon Port Allocation [4]. The 08ID-1 beamline will be the longest beamline at the CLS facility.

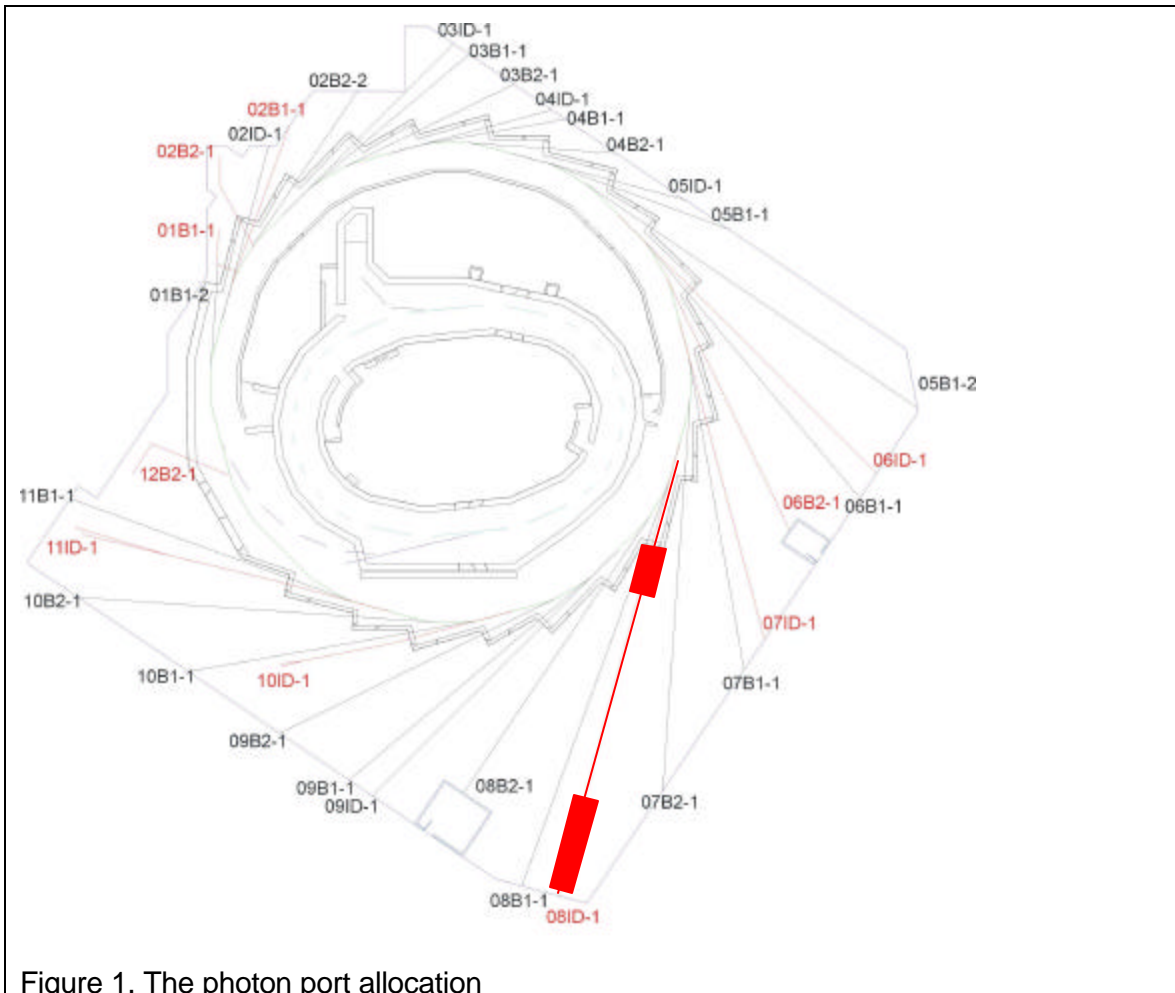


Figure 1. The photon port allocation

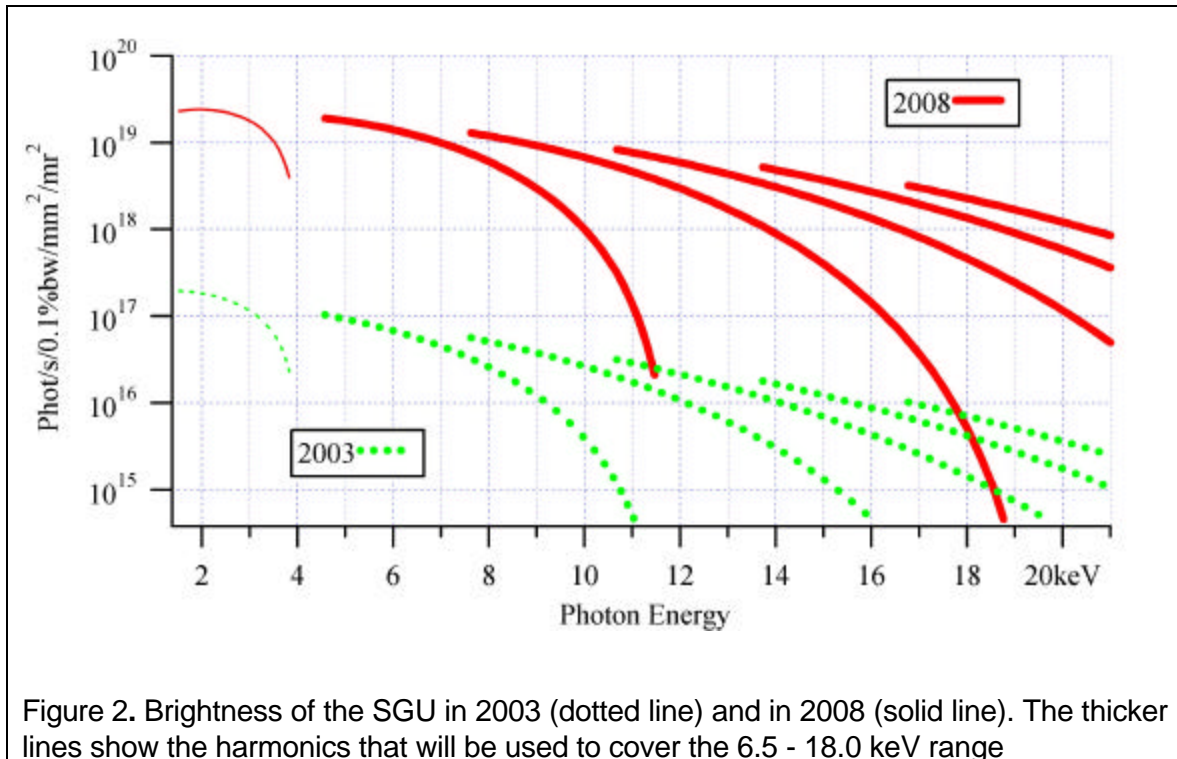
## 3.0 UNDULATOR

The 08ID-1 beamline will be illuminated with a small gap in-vacuum undulator SGU. The design of the undulator is described in the CLS Preliminary Design Report 6.2.25.4 [5]. The SGU will be located 0.955 m upstream from the center of the straight section to facilitate the future option of chicaning two SGU's in the 08 straight section. The summaries of the properties of the SGU are in Tables 1 & 2. The beamline controls will be compatible with the software for controlling the SGU.

**Table 1. Properties of the SGU undulator**

Undulator Type	Hybrid	
Undulator Layout	Asymmetric	
Period Length	20 mm	
Minimum Gap	5 mm	
Maximum Gap	About 30 mm	
Number of Full Size Poles	157	
Total Number of Poles	159	
Length of Magnet Assemblies	1583 mm	
At Minimum Gap:	Peak Flux Density	1.066 T
	Effective Flux Density	0.981 T
	Effective K	1.83
	Higher Order Contributions	8.4%
	Photon Energy, n = 1	1.49 keV
	Maximum Magnetic Load	9.5 kN
Magnetic Material:	Permanent Magnet Blocks	Sm <sub>2</sub> Co <sub>17</sub>
	Minimum Remanence	1.03 T
	Minimum Intrinsic Coercivity	20 kOe
	Temperature Coefficient, Intr. Coercivity	-0.19 %/°C
	Poles	Vanadium Permendur
Total Power	4.0 kW	

The SGU undulator is the best suited undulator design covering the most important energy range from 4.6 – 20 keV, which corresponds well with the desired spectral range for this beamline (6.5 – 18.0 keV) (Fig. 1). To cover this range we will use 3<sup>rd</sup>, 5<sup>th</sup>, 7<sup>th</sup>, 9<sup>th</sup> and 11<sup>th</sup> harmonics



**Table 2. Insertion device source characteristic at 12 keV (from 7<sup>th</sup> harmonic)**

	<b>Beginning of operation</b>	<b>After 1-2 years of operation</b>	<b>Long-term goal</b>
On-axis calculated brilliance	$\sim 2 \times 10^{16}$ ph/s/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw	$\sim 5 \times 10^{17}$ ph/s/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw	$\sim 4 \times 10^{18}$ ph/s/mrad <sup>2</sup> /mm <sup>2</sup> /0.1%bw
$\Sigma_x$ [mm]	0.559	0.465	0.441
$\Sigma_y$ [mm]	0.088	0.022	0.009
$\Sigma_{x'}$ [mrad]	0.056	0.045	0.043
$\Sigma_{y'}$ [mrad]	0.035	0.011	0.007

## 4.0 FRONT END

The design of the front end for the 08ID-1 beamline is based on the APS design and is described in the CLS Front Ends Design Note (CLS 6.2.26.2) [6]. The front end can handle the total power of the in-vacuum undulator (4.0 kW) and its FE FM4 aperture will provide a beam of  $200 \mu\text{rad} \times 100 \mu\text{rad}$  (h x v) transmitting power of 516 W to the beamline pipe.

## 5.0 BEAMLINE DESIGN

### 5.1 BEAMLINE LAYOUT

The optics of the 08ID-1 Beamline consists of:

- Primary aperture
- Double crystal monochromator (with constant height of the exit beam) with a horizontally (sagittally) focusing second crystal
- A vertically focusing bent plane mirror which also removes harmonics

The schematic layout of the beamline is shown in Fig. 3.

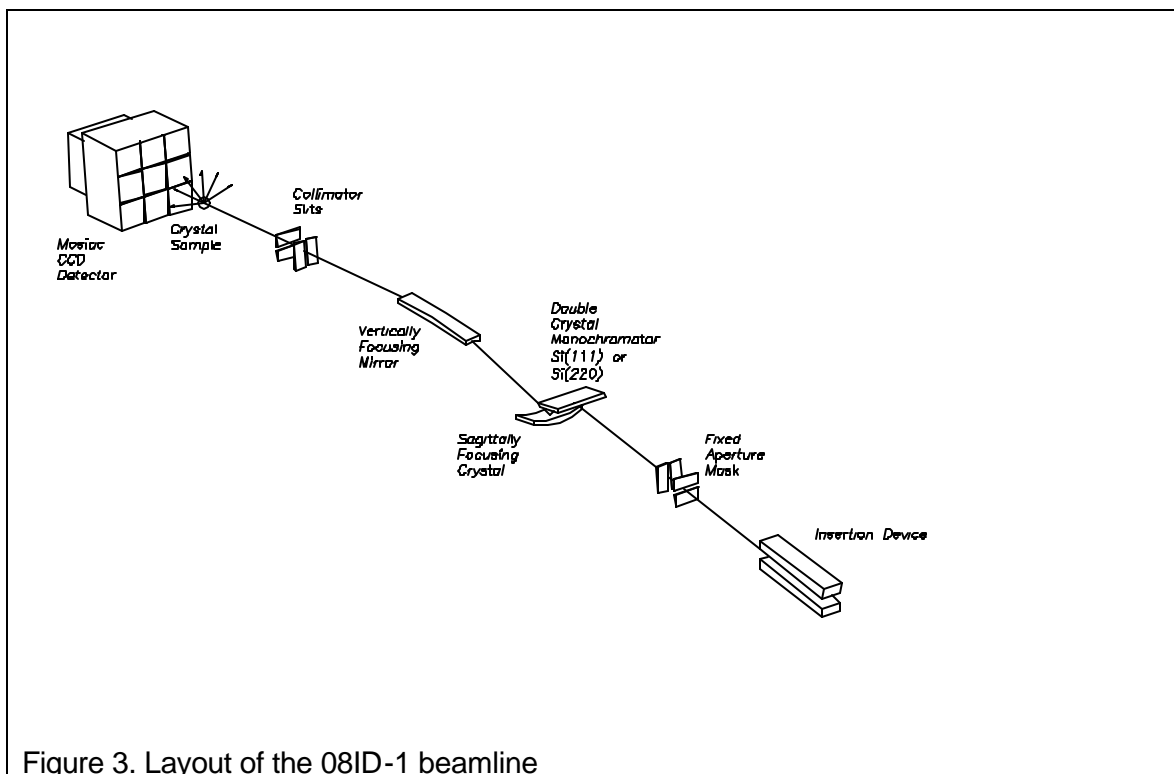


Figure 3. Layout of the 08ID-1 beamline

The overall beamline layout (Drawing 08ID-1/ME/0048300 Rev. A) shows the entire sector and not just the 08ID-1 beamline in order to demonstrate the ID beamline's

relationship to and compatibility with the future Bending Magnet (BM) beamlines. Drawing 08ID-1/ME/0054300 Rev. A shows views of the optical components, support structures and vacuum systems for the ID beamline.

## 5.2 OVERVIEW OF BEAMLINE OPTICS DESIGN

The general design principle is to use X-ray optics that cover a wide energy range, allow for a wide adjustment range of the beam size at the sample and are able, if maximum flux density is required, to focus the flux from the undulator into a small point matched to the pixel size of the detector and to the ever decreasing size of sample crystals. Another design principle is to preserve the high collimation of the beam for resolving the diffraction patterns of samples with very large unit cell dimensions.

These design goals are well met by the optical layout of the SBC: a double crystal monochromator with a sagittally focusing second crystal stage followed by a dynamically bent plane mirror in a highly demagnifying arrangement.

The performance of the SBC ID beamline and that to be expected for the CMCF 08ID-1 beamline is shown in Table 3.

**Table 3. SBC beamline performance and that expected for 08ID-1beamline**

<u>Parameter</u>		<u>SBC</u>		<u>08ID-1</u>	
		<u>Design</u>	<u>Measured</u>	<u>Design</u>	
Energy range	Si(111)	3.5 - 15	5.0 - 18	6.5 –18	keV
	Si(333)		to 36	n/a	keV
	Si(220)	5.6 – 25		6.5 –18	keV
Energy resolution $\Delta E/E$	Si(220)	n/a	n/a	0.55	* $10^{-4}$
	Si(111)	1.5	1.4	1.40	* $10^{-4}$
Flux (Si(111), 12 keV, 1 <sup>st</sup> harmonic for SBC and 7 <sup>th</sup> for CMCF)			$1.2 \times 10^{13}$ @100 mA	$5 \times 10^{12}$ @500 mA	photons/s
Harmonic contamination		0.1	<0.04	0.1	%
Rate of energy change	@ 6.5 keV	50	350	200	eV/s
	@ 20 keV	300		2000	eV/s (Si(220))
Minimum focal size at sample	Vertical	0.15	0.04	0.05	mm FWHM
	Horizontal	0.3	0.08	0.15	mm FWHM
Beam position stability		0.05	<0.01	0.01	mm
Efficiency		60	80	70	%

The locations of the egress routes for the beamline 08ID-1 are shown in Drawing 08ID-1/ME/0048300 Rev. A. The aisle between beamline 07B2-1 and 08B1-1 will be surveyed and marked on the floor to insure an appropriate width of the egress aisle. Based on this, the horizontal position of the beam pipe feedthrough of enclosures 08ID-C and 08ID-D has been determined so that the enclosures will be accurately placed and not intrude into the egress aisle.

CLS personnel will complete an extensive survey of the 08ID-1 beamline with placement of all the reference fiducials and survey monuments, where the scale starts in the centre of the straight section. In addition, they will survey the height from the floor to the beam centreline at key positions along the beamline for accurate dimensioning of the enclosure beamline penetrations, heights of all support stands, and placement of the white-beam transport system. All construction tolerances on the radiation enclosures are specified and should be accurate to 6 mm (0.25 inches). Tolerances of  $\pm 6$ mm have been specified for the penetrations of the beam pipes through the enclosure walls. Survey markers at a suitable distance parallel to the beam centre line will be laid down on the floor. These markers will be used to survey the location of optical and other critical components to better than 1 mm. Location of components inside vacuum tanks are known to <1mm relative to references on the outside of the tanks. This method has been used before at the SBC.

### **5.3 BEAMLINE PROCESS FLOW DIAGRAMS (PFDS) AND PROCESS AND INSTRUMENTATION DIAGRAMS (P&IDS)**

The beamline is designed to be UHV compatible and will be eventually operated in a windowless mode. The design will be based on a pressure of  $1.3 \times 10^{-6}$  Pa ( $10^{-8}$  Torr) at the front of the beamline and  $1.3 \times 10^{-5}$  Pa ( $10^{-7}$  Torr) at the downstream end of the beamline. The main ion pumps will have a pumping speed of 300l/s, and the monochromator will be equipped with a 500l/s ion pump. The total number of pumps at the beamline are as follows, five 300 l/s turbo pumps, one 500 l/s, four 300 l/s, and two 40 l/s ion pumps, respectively. Gate valves will be used to isolate each of the major beamline components, each section between valves will have pressure gauges and roughing port to allow the region to be pumped down using portable turbo-molecular pumps. The vacuum design will be based on the CLS High Vacuum Design Specification 8.4.33.1 Rev 2 [7]. The preliminary design has no water-to-vacuum joints, and utilizes viton O-ring seals for the lid of the monochromator, mirror chambers, and gate valves.

CMCF will use optical and shielding apertures similar to those used for SBC and implemented at SER-CAT. The CLS mask in the 08ID frond end, FE FM4, will have an optical aperture of  $200 \mu\text{rad} \times 100 \mu\text{rad}$ . The CMCF's beam defining mask, located at 41.8 m, will have an aperture of 6.0 mm x 2.0 mm (h x v) which translates to  $143 \mu\text{rad} \times 48 \mu\text{rad}$  beam divergence. The cooling requirement for this mask will be deionised water (DI) at 21°C with 0.12 l/sec flow.

All other optical and shielding apertures that are not sufficiently cooled to absorb the white beam are at least 2.0 mm away from the envelope of the external ray for synchrotron radiation as shown in the x-ray tracing drawings (Preliminary Safety Report, drawing 08ID-1/ME/0054530 Rev. A, 08ID-1/ME/0054520 Rev. A). The tapered

absorber area of the photon absorber is 4mm wider in horizontal and vertical directions than the area illuminated by the extreme rays.

Monochromatic apertures are more than twice as large as the size of the beam collimated by the primary aperture. The power of the monochromatic beam of 15 mW maximum does not pose any problem for downstream apertures nor should the beam hit any other component (For Si(111) the mono flux at 18 keV would be  $\sim 5 \times 10^{12}$  ph/s, so  $P[W] = 5 \times 10^{12}$  [ph/s]  $\times 18 \times 10^3$  [eV/ph]  $\times 1.602 \times 10^{-19}$  [J/eV] = 0.015 W).

The total requirement for 21°C DI for the 08ID-1 the beamline is 0.6 l/sec.

The consumption of LN<sub>2</sub> at the beamline is about 700 liters per week.

Pressurized air to the timing shutter should be 689.7 kPa (100 psi), adjusted with regulator in the hutch.

Drawings:

Beamline Optical PFD:	Drawing 08ID-1/PFD/0054601 Rev. A
Beamline Vacuum PFD:	Drawing 08ID-1/PFD/0054611 Rev. A
Beamline PID	Drawing: 08ID-1/PID/0054650 Rev. A, 08ID-1/PID/0054651 Rev. A, 08ID-1/PID/0054652 Rev. A
Beamline Cooling Water PID:	Drawing: 08ID-1/PID/0054621 Rev. A
Beamline Pneumatic PID:	Drawing 08ID-1/PID/0054631 Rev. A
Beamline Gases PID:	Drawing 08ID-1/PID/0054641 Rev. A

## 5.4 COMPONENTS DESIGN

In this section descriptions of the designs used for major ID beamline components are provided. For those items described as unmodified APS or SBC designs, only minimal descriptions will be provided because these designs have previously been reviewed in depth. For those items that have been substantially modified from previous designs or represent new designs we will provide detailed descriptions. In Appendix 1, copies of the key assembly drawings cited in this section are provided. The numbers used in the titles in this section are from the work breakdown structure (WBS).

### 5.4.1 WBS 1.61.30.20.A Shielding

The 08ID-1 beamline requires shielded enclosures. These include 08-ID-A, first optical enclosure, White Beam Transport, 08-ID-C hutch and 08-ID-D – the experimental hutch. The A, C hutches and WBT have to provide appropriate shielding required for the white beam produced by the SGU undulator. The dimensions, placement, and construction of the ID radiation enclosures will be similar to those previously approved and installed at

APS for the SBC with the modifications including the thickness of the lead shields appropriate for the CLS radiation.

Design basis:

- 08-ID-A: APS 4-ID-A (Standard APS' FOE, modified door actuation and beam pipe feed-through, Drawing SER 1.1.1.1.2-002-DD)
- 08-ID-C: APS 4-ID-A, SER-CAT and SBC-CAT improved design
- 08-ID-D: APS 3-ID-A, SER-CAT and SBC-CAT improved design

CLS Status: Design in progress. Design Note 6.2.77.1 submitted on July 19, 2001 [8].

#### **5.4.2 WBS 1.61.30.20.A.2 White Beam Transport**

The White Beam Transport (WTB) is a vacuum pipe with the 12.7 mm (0.5 ") lead shielding. Its design is similar to that of SBC-CAT and Bio-CAT.

Design basis: SBC-CAT approved design  
 Drawing: SBC 1.1.2.4.1.2-050-DD rev. 0F  
 Bio-CAT approved design

CMCF Status:

Design in progress: Design Note 6.2.77.1 submitted on July 19, 2001.

#### **5.4.3 WBS 1.61.30.20.A.3 Guillotine Shield**

The guillotine is needed to facilitate movement of the Down Stream Support pivoted at the center of the mirror. The guillotine shield design is the same as that of SER-CAT. The shielding design is in compliance with the CLS shielding standards calling for 5mSv/yr outside of the hutches.

Design basis: SBC approved design  
 Drawings: SBC 1.1.2.2.2.4-051-DD rev. 0B;  
 SBC 1.1.2.2.2.4-052-DD rev. 0A.  
 Bio-CAT approved design  
 Drawings: BIO 1.1.1.4.2.4-051-DD rev. 0D;  
 BIO 1.1.1.4.2.4-052-DD rev. 0A;

CMCF Status: Design adapted

Drawings: 08ID-1/ME/0054100 Rev. A.

#### **5.4.4 WBS 1.61.30.20.A.6 Bremsstrahlung Shielding**

The first Bremsstrahlung collimator downstream of the ratchet wall in the A-hutch is part of the front end. All other CMCF provided Bremsstrahlung collimators and stops are made from lead blocks of basic size 203.2 mm x 101.6 mm x 50.8 mm (8" x 4" x 2"). All Bremsstrahlung shields are 305 mm (12.0") long. The outside dimensions of all blocks are at least 50 mm larger than the intersection with the extreme rays (CMCF 08ID-1 Preliminary Safety Report [9]; Drawings: 08ID-1/ME/005450 Rev. A and 08ID-1/ME/0054510 Rev. A). The opening for the monochromatic beam through the Bremsstrahlung Stop is 10 mm below the line of sight of the extreme ray.

Design basis: SBC approved designs

Collimator 1:	Drawing SER 1.1.1.1.2.6-050-DC Rev. 1B,
Collimator 2	Drawing SER 1.1.1.3.2-052-DC Rev. 1C,
Collimator 3 (Stop)	Drawing SER 1.1.1.3.2-053-DC Rev. 1C

CMCF Status: Design revised

Collimator 1:	Drawing 08ID-1/ME/CLM/0054150 Rev A
Collimator 2:	Drawing 08ID-1/ME/CLM/0054144 Rev A
Collimator 3 (Stop):	Drawing 08ID-1/ME/CLM/0054160 Rev A

The supports for the collimators are similar to those used at SER-CAT and are designed to safely support the weight of lead (<150 kg). The supports for Collimators 2 and 3 are designed to also support the vacuum tank of the monochromator. The supports are also dimensioned to safely stand up to the atmospheric forces on the vacuum bellows.

Design basis: SBC approved designs

Collimator 1 Support	Drawing SBC 1.1.2.4.1.9-053-DD rev. 0C
Collimators 2 & 3 Supp.	Drawing SBC 1.1.1.2.5-050-DE rev. 0F

CMCF Status:

Collimator 1 Support:	Drawing 08ID-1/ME/SPT/006372 Rev. A
Collimators 2 & 3 Supp.:	Drawing 08ID-1/ME/MNC/0055900 Rev. A

#### **5.4.5 WBS 1.61.30.20.A.7 Photon Shutter**

The Photon Shutter is a part of the PSS system. Its design is identical to that used by SBC and SER-CAT. The SBC design, in turn, is a modified version of the APS monochromatic shutter.

Design basis: SBC approved designs

Drawing: SBC 1.1.1.4.1-050-DE rev.0B  
 CMCF Status: Design adapted  
 Drawing: 08ID-1/ME/BDP/0054700 rev. A

#### **5.4.6 WBS 1.61.30.20.A.8 Personnel Safety System**

The IEC 61508 Safety Integrity Level 3 certified PLC System will be used to control the PSS at all CLS beamlines. The PSS for the CMCF 08ID-1 beamline is described in the CMCF 08ID-1 Preliminary Safety Report (6.2.77.3) [9]. The search plan is provided on the drawing 08ID-1/ME/SFY/0056725.

#### **5.4.7 WBS 1.61.30.20.A.9 Oxygen Deficiency Monitors**

Because liquid nitrogen will be used in the ID-C and D enclosures, oxygen deficiency monitors will be provided as a safety measure. The oxygen deficiency monitors will be in accordance with CLS standards.

#### **5.4.8 WBS 1.61.30.20.B.1 Primary Aperture**

On the undulator line, the angular width of the heat-load distribution is much larger than the width of the used radiation. Thus a primary aperture can be used to absorb most of the heat while passing most of the radiation. The 08ID-1 primary aperture (mask) will be similar to the SBC-CAT primary aperture (designed by Gerd Rosenbaum and running at the SBC-CAT undulator beamline for the last five years). This mask receives up to 2.8 kW from an upstream aperture of  $180 \mu\text{rad} \times 180 \mu\text{rad}$ . The SBC-CAT aperture is cooled with water supplied at  $21^\circ\text{C}$  and a 0.12 l/sec flow rate. The aperture is capable of absorbing up to 8.5 kW in case the APS will be running at 300 mA, but then cooling would have to be supplied with 0.6 l/sec water flow at room temperature ( $21^\circ\text{C}$ ).

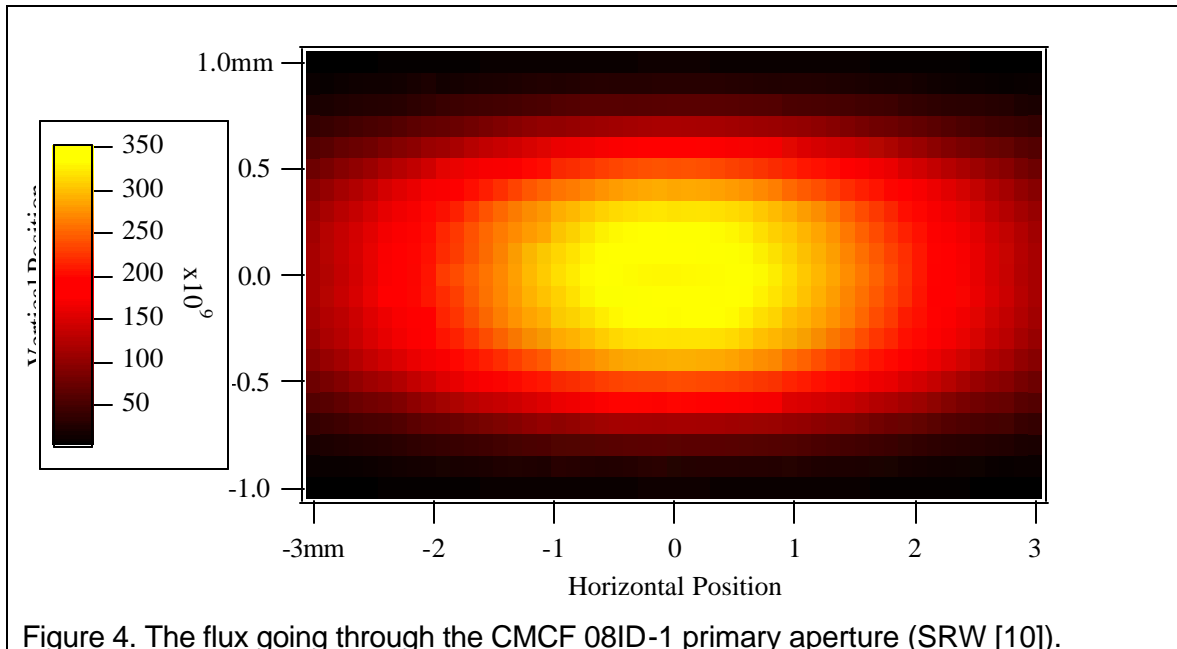
The new front end installed for the SER-CAT provides beam of  $120 \mu\text{rad} \times 80 \mu\text{rad}$  and allows the maximum heat load on the SER-CAT mask of 1.16 kW.

The SBC design primary aperture is suitable for the CMCF 08ID-1 beamline. The copper aperture will receive 516 W from the front end CLS FM4 mask. The horizontal opening of the CMCF 08ID-1 primary aperture will equal 37.3 mm (28.3 mm (horizontal photon size) + 6 mm (travel of the aperture) + 2 x 0.5 mm (over travel) + 2 x 1.0 mm (margin)). The mask will contain an aperture of 6.0 mm x 2.0 mm (horizontal x vertical). It will reduce the maximum thermal load on the first crystal of monochromator to 188 W, which can be removed by cryogenic cooling, while transmitting more than 85% of the mono flux at 12 keV (Table 4). The flux going through the 08ID-1 primary aperture is shown on the Fig. 4 (CLS 2008 conditions).

**Table 4. Flux vs. aperture and total power transmitted to the first crystal of the monochromator**

<b>Aperture at 42m</b> [mm x mm]/ [μrad x μrad]	<b>Flux [ph/s/0.1%bw]</b> (K=1.62579, E=12.030 keV, 7 <sup>h</sup> harmonic) <b>x10<sup>14</sup></b>	<b>Total Power</b> [W]
3.00x1.00/ 71x24	0.81	46
3.60x1.20/ 86x29	1.04	66
4.20x1.40/ 100x33	1.24	93
4.80x1.60/ 114x38	1.37	121
5.40x1.80/ 128x43	1.48	153
<b>6.00x2.00/ 143x48</b>	<b>1.55</b>	<b>188</b>
6.60x2.20/ 157x52	1.61	227
7.20x2.40/ 171x57	1.66	268
7.80x2.60/ 186x62	1.70	313
8.40x2.80/ 200x67	1.73	361
9.00x3.00/ 214x71	1.75	414
10.5x3.30/ 250x83	1.77	516
12.0x4.00/ 286x95	1.79	516

*The flux and total power transmitted through the mask/aperture were calculated using SRW and XOP (XUS 2.0) (method: Non-zero emittance, infinite-N with convolution). For power calculations, the numbers of periods were taken to be 81.*



Design Basis: SBC design

Drawings:

Mask: SBC 1.1.2.3.3.1.1-050-DD rev.0E

Positioning System: SER-CAT's design

Support stand: Drawing SBC 1.1.2.3.3.3-052-DE rev.0B

CMCF Status:

Mask: Design in progress

Positioning System: SER-CAT's design

Support stand: under design

#### **5.4.9 WBS 1.61.30.20.B.2 Monochromator**

Specifications:

- 6.5 – 18.0 keV standard spectral range
- Bragg-angle reproducibility 2  $\mu$ radian
- Si(111) or Si(220) double crystal
- First crystal cryo-cooled
- Second crystal sagittally bent
- Temperature stabilization of monochromator to 22° C  $\pm$  1° C by separate water cooling/heating circuit with water temperature 22° C  $\pm$  0.1° C.

- 6.5° – 38° Bragg angle range
- 31 mm beam offset
- Motorized tune, twist and roll control (4mm range, 50 nm resolution)
- Supported by a vibration isolation base
- Isolated from the vacuum envelope

The Rosenbaum-Rock double-crystal monochromator is a very good candidate. The monochromator is an improved version of the SBC-CAT monochromator and will be a nearly exact copy of the 22-ID SER-CAT monochromator. The major change from the SBC monochromator is a new rail and slide for the translation of the second crystal providing a much tighter angular tracking. A second major change is the reduction of the vertical offset between the incident and the monochromatic beam from 35 mm to 31 mm, which provides a wider energy range for the same compactness of the monochromator mechanics. As shown in the 08ID-1 Preliminary Safety Primary Report, this is in compliance with the requirements for Bremsstrahlung shielding.

Other minor changes include a small increase in the size of the tank for easier integration of the photon absorber, relocation of the view ports to allow better views of the interior components, and re-arrangement of feedthroughs based on experience at the SBC and BioCAT. The photon absorber, which is part of the PSS system, is similar to the design used at the SBC and BioCAT. The tapered absorber area of the photon absorber will be 4 mm wider in horizontal and vertical directions than the area illuminated by the extreme rays (08ID-1/ME/0054530 Rev. A, 08ID-1/ME/0054520 Rev. A).

Initially we will use Si(111) crystals to get more flux, but eventually we may use the Si(220) crystals to get smaller bandwidth. The first crystal has a hockey puck shape with cooling fins located opposite to the active area. The total LN<sub>2</sub> contact area is 200 cm<sup>3</sup>. The LN<sub>2</sub>-cooling system for the first crystal could be an Oxford Instruments Liquid Nitrogen Cryo-Cooler, Series D, as at the SER-CAT revision. LN<sub>2</sub>-transfer lines will connect the CLS ring line to a buffer Dewar and a distribution manifold, similar to the one at the BioCAT.

The crystals of the double crystal monochromator have to stay aligned with respect to each other within 1 μradian in order to keep the monochromatic beam centred on the collimator slits. Larger angular misalignment will also cause loss of intensity. The major cause of loss of alignment is small distortions of the monochromator mechanics due to temperature changes: on the one hand, radiative heat loss to the LN<sub>2</sub>-cooled first crystal manifold and, on the other hand, radiative heating by scattered radiation. Like the SBC, we will use a cooler/heater with high temperature stability of <0.1°C to pump cooling/heating water through a closed loop inside the monochromator vacuum tank. The loop attaches via Cu-pads to the base plate of the first crystal mount, the scattered radiation skirt, the base plate of the second crystal translation and the bracket for the first crystal mount. We will use the SER-CAT design of scatter shield and thermal isolation, which incorporates all modifications added by Bio-CAT to the original hockey puck design.

Design basis: SBC approved design

monochromator: Drawing SBC 1.1.2.3.5-050-DE rev 0E

cryo-crystal: Drawing SBS 210-017 rev 0A  
 photon absorber: Drawing SBC 1.1.2.3.5-058-DE rev 0C  
 thermal stabilization: Drawing: SBC 1.1.2.3.5-051-DE rev 0C

CMCF Status:

Drawings: monochromator: 08ID-1/ME/MNC/0055900 Rev. A.  
 photon absorber: design in progress  
 cryo-crystal: 08ID-/ME/MNC/0054550 Rev. A.  
 second crystal: 08ID-1/ME/MNC/0054555 Rev. A.  
 thermal stabilization: 08ID/ME/MNC/0055925 Rev. A.

#### **5.4.10 WBS 1.61.30.20.B.3 Vertical Focusing Mirror**

Specifications:

- Substrate material & dimension options:

Material	Length (mm)	Width (mm)	Height (mm)
Zerodur®	1000	90	39
Ultra Low Expansion glass	1000	90	43
Silicon	1000	90	31

- 2 Å rms roughness and 1µrad surface figure error
- Pt, none, Pd coating stripes (30 mm wide across width)
- Motorized, encoded supports
- Dynamic, independent bending mechanisms at both ends
- Aberration correction via elliptical bending

The Rosenbaum-Rock Vertical Focusing Mirror assembly design is the best choice. It is virtually identical to the SBC design. The design, which allows dynamic elliptical bending corrections, has worked very successfully at the SBC and at BioCAT producing vertical foci as small as 0.015 mm FWHM at 10:1 demagnification. Several small improvements include increasing the height of the tank by a small amount for more space between bending mechanism and substrate, increasing the length of the substrate 100 mm beyond the active area at both ends, modifying the substrate suspension design to remove an observed residual curvature, and relocating the view ports.

Design basis SBC approved design

Drawing: SBC 1.1.1.2.6-050-DE rev 0K

CMCF status: Design adapted

Drawing: Mirror assembly: 08ID-1/ME/MIR/0055400 Rev. A

Mirror-substrate: 08ID-1/ME/MIR/0055450 Ref. A.

#### **5.4.11 WBS 1.61.30.20.B.4 Photon Beam Monitors**

Specifications: The white beam position has to be determined to within 0.05 mm and the monochromatic beam position has to be determined with an accuracy of 0.002 mm.

The very small foci achievable at the CLS require a very high accuracy of beam steering and high stability of the focus in order not to degrade the performance of the optics.

The concept of the white beam monitors integrated into the primary aperture mask has been proven to be a very good solution. The design is copied from the SBC. The temperatures of the tapered, beam absorbing faces of the mask are measured. Beam position is linearly proportional to the difference/sum of the temperature increases of opposing faces and can be determined to about 0.03 mm (vertical) and 0.05 mm (horizontal).

For monochromatic beam position monitoring, a design developed at the SBC, will be used [11]. The fluorescence from a 0.5  $\mu\text{m}$  thick Cr-foil inserted into the beam is recorded by four photodiodes spaced at 90° intervals. Beam position is a linear function of the difference/sum of the signal from opposing diodes. Sensitivity is better than 0.001 mm. Accuracy is about 0.002 mm.

The same device, located in the guard slits box will be used as the  $\downarrow$  monitor of the photon beam (Figure 5b).

Design basis

White beam: drawing      SBC 1.1.2.3.3.1.1-050-DD rev.0E

CMCF Status: Design adapted

Drawing:      white beam: Design in progress      monochromatic: see Figure 5.

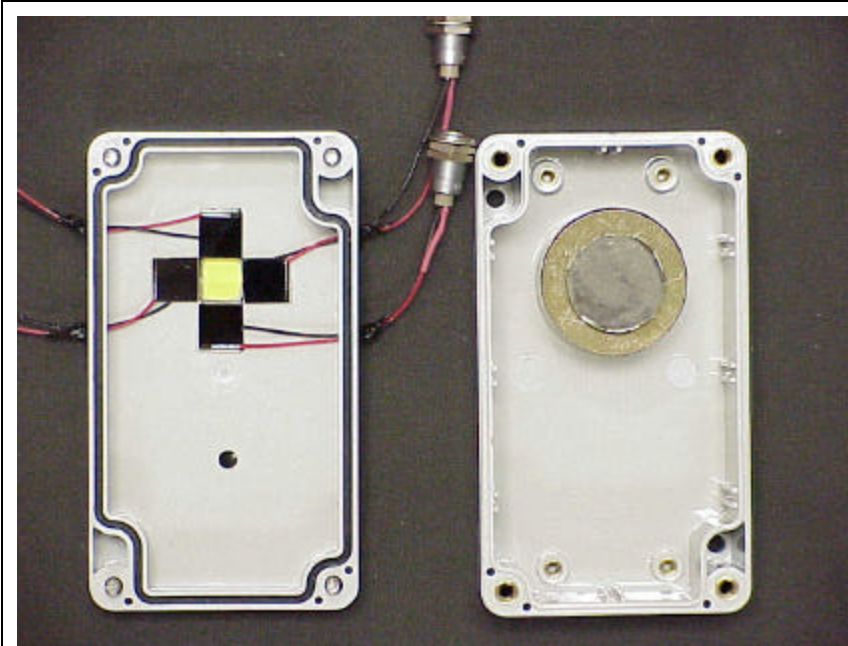


Figure 5a. Monochromatic BPM (Courtesy Gerd Rosenbaum, SER-CAT)

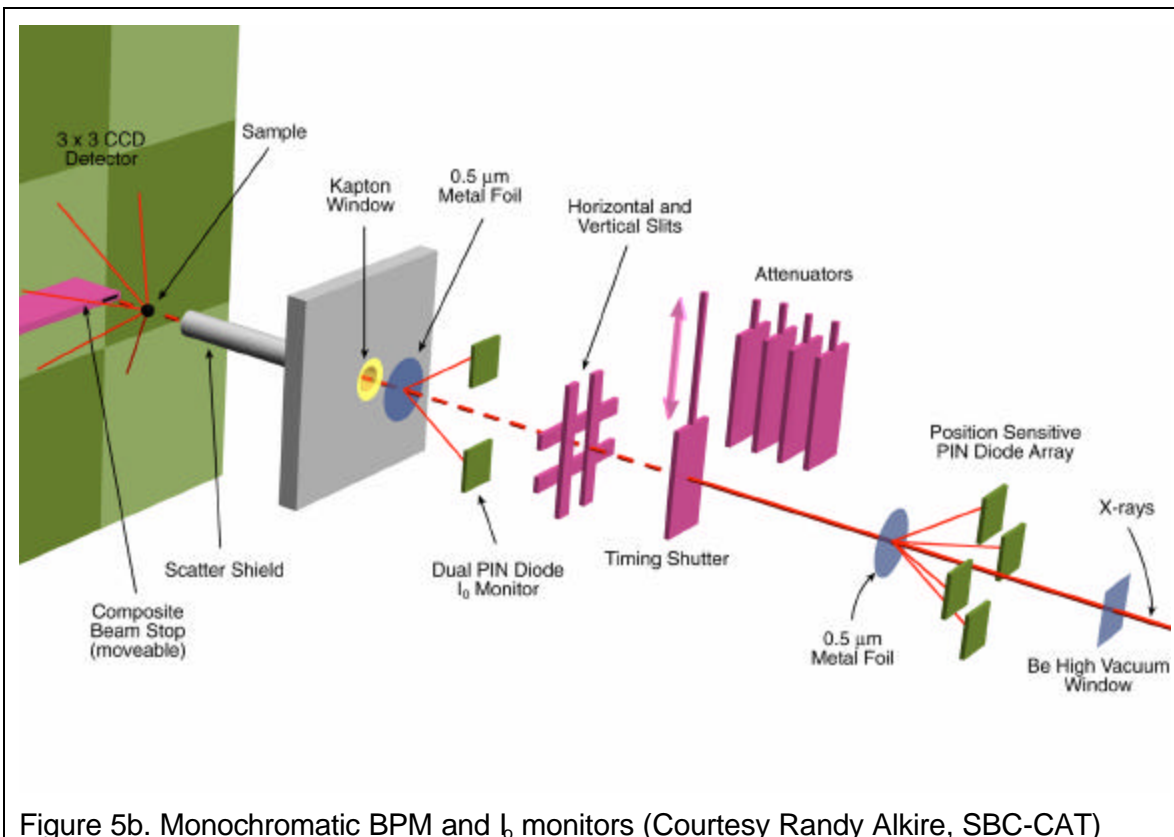


Figure 5b. Monochromatic BPM and  $I_0$  monitors (Courtesy Randy Alkire, SBC-CAT)

#### **5.4.12 WBS 1.61.30.20.C Vacuum & Photon Beam Transport**

Ultra-high to high vacuum has to be maintained between the front end and a Beryllium window located in the monochromatic beam path in the D-hutch. UHV-grade components will be used throughout the beamline. The rest of the beamline up to 80 mm from the sample will be held at a low vacuum. Almost all vacuum components, except a few custom length beam pipes and the tanks of monochromator, mirror, etc., will be catalogue items available from standard suppliers. Some minor changes to be made by CMCF include reduction of the port size of some gate valves and reduction of the diameter of in-line bellows.

Design basis: Drawing SBC 1.1.2.3-002-DD rev.0G

CMCF Status: Design completed

Drawing: 08ID-1/ME/0054300 Rev. A.

#### **5.4.13 WBS 1.61.30.20.D Utilities**

The utility layout for the ID beamline is similar to that of SBC. The changes from the SBC design will include relocation of cable trays, panel boxes, the electronic racks, etc. The electrical utility layout has not been approved yet. Other utilities are a water skid for cooling the primary aperture mask and the photon absorber located inside the monochromator and LN<sub>2</sub>.

Design basis SBC approved layout

electrical	SBC 1.1.2.5.2-001-DD rev 0E (B0028E)
	SBC 1.1.2.5.2-003-DD rev 0C
cable trays	SBC 1.1.1.4.2-001-DD rev 0M
di-water skid	SBC 1.1.2.5.1-050-DD rev 0A
di-water piping	SBC 1.1.2.5-001-DD rev 0E
compressed air piping	SBC 1.1.2.5-001-DD rev 0E

CMCF Status: electrical	Design in progress
cable trays	Design in progress
di-water skid	Design in progress
di-water piping	Design in progress
compressed air piping	Design in progress

#### **5.4.14 WBS 1.61.30.20.E Photon Beamline Instrumentation & Control**

Like the SBC, the CMCF will use servomotor controllers for beamline control. But we will use a newer version of the hardware used by the SER-CAT, with more functionality and lesser need for cabling at a lower cost. There are essentially two options being considered for the CMCF's beamline control software. The first is based on the MX software suite, developed by Bill Lavender and Jim Fait for the IMCA-CAT and being successfully used there. The SER-CAT is also using the MX suite and the SBC-CAT is working with Bill Lavender to implement it on the EPICS layer. As the CMCF beamline operation matures, software upgrades will be implemented which will include integration of a robotic sample placement and alignment system, and limited experiment control via the Internet from the users' home labs. A collaborative effort in further development of the MX suite, initiated with other macromolecular crystallography beamlines will help their efforts.

The second option for the beamline control software is Blu-Ice, which Tim McPhillips developed at the SSRL. Blu-Ice probably has the user-friendliest GUI available, but its servers have not been implemented on the proposed beamline yet. There are several options to implement it. One is to write the Blu-Ice DHS server that uses MX or EPICS to talk to actual hardware. Another option is the Blu-Ice GUI for the EPICS running the beamline, which Ed Westbrook, Tom Coleman and Bob Daly are implementing at the 4.2.2 ALS beamline.

There are some efforts from the Alberta Synchrotron Institute to finance the adaptation of the Blu-Ice to the CLS hardware. Implementation of Blu-Ice on the CLS hardware will require at least one year of work by a skilled programmer.

Whichever version of the software will be chosen an effort will be made to apply CLS software engineering standards [12]. Custom electronics and instrumentation will be developed following CLS electronics development standards [13].

Design basis:

hardware: SER-CAT beamline hardware, new version of motor controllers, amplifiers and interconnects

software: MX and/or Blu-Ice beamline control suite

#### **5.4.15 WBS 1.61.30.20.G. Data Acquisition and Data Processing**

The design of CMCF's endstation instrumentation and data acquisition systems will be based upon that of SBC but substantially upgraded based upon SBC's operating experiences and on the emergence of new technologies since the implementation of SBC's systems over the past ~5 years (Fig. 6). The SBC endstation instrumentation, which provides free access to the sample area, has been extremely well received by the users.

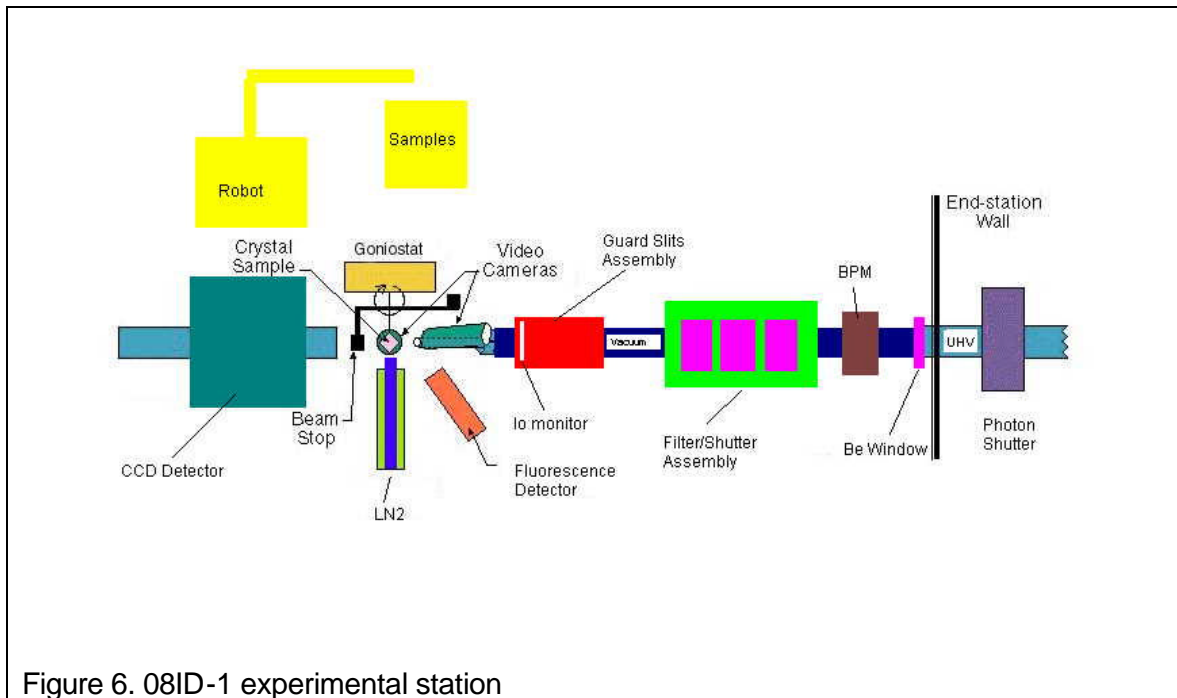
CMCF plans to continue using CCD based detectors of large area, e.g., 315 mm x 315 mm, with faster read out speeds (MB/sec) and a faster, more versatile data acquisition system. Several options are being considered such as: Quantum 315 from ADSC, Proteum 300 from Bruker, or a 4 x 4 CCD detector custom built at the ECT Department

of the APS. Very large and fast detectors combined with high flux from the SGU will require large storage capacity of about 300 Gb data per 24h.

The detector support will be the same overhead design used at the SBC but modified for the new larger size of detectors such as ADSC Q315 or Bruker Proteum 300 that is already implemented at the SER-CAT beamline.

CMCF also intends to install a robotic sample placement and alignment system to dramatically increase the efficiency of structure determinations. The robot and alignment of crystal in the beam will be an integrated part of the beamline controlling software. At this stage there are several options available and the CMCF will decide after additional studies which system to implement.

The computer system will be a current state-of-the-art system with commensurate enhancements of all the data acquisition and analysis software with large data storage capacity (Tb).



Design basis Goniometer: Drawing SBC 1.1.2.6.1.2-053-DE, rev. 0J  
 Guard slits: Drawing SBC 1.1.2.6.1.5-050-DC, rev. 0A  
 Beam stop positioner Drawing SBC 1.1.2.6.1.6-053-DD, rev.0A  
 Detector positioner: Drawing SBC 1.1.2.6.1.3-052-DE, rev.0E

CMCF Status: Goniometer Design update in progress  
 Guard slits Completed (no change)

Beam stop positioner Completed (no change)  
 Detector positioner Design update in progress

Drawings: Goniometer 08ID-1/ME/0054800 Rev. A (sheets 1 & 2)  
 Guard slits 08ID-1/ME/CLM/0055800 Rev. A.  
 Beam stop positioner 08ID-/ME/BPD/0055700 Rev. A.  
 Detector positioner Design in progress

## 6.0 WORK BREAKDOWN STRUCTURE

Work Breakdown Structure contained in CMCF's Management Plan is shown below.

### 1.61.30.20 PRELIMINARY DESIGN

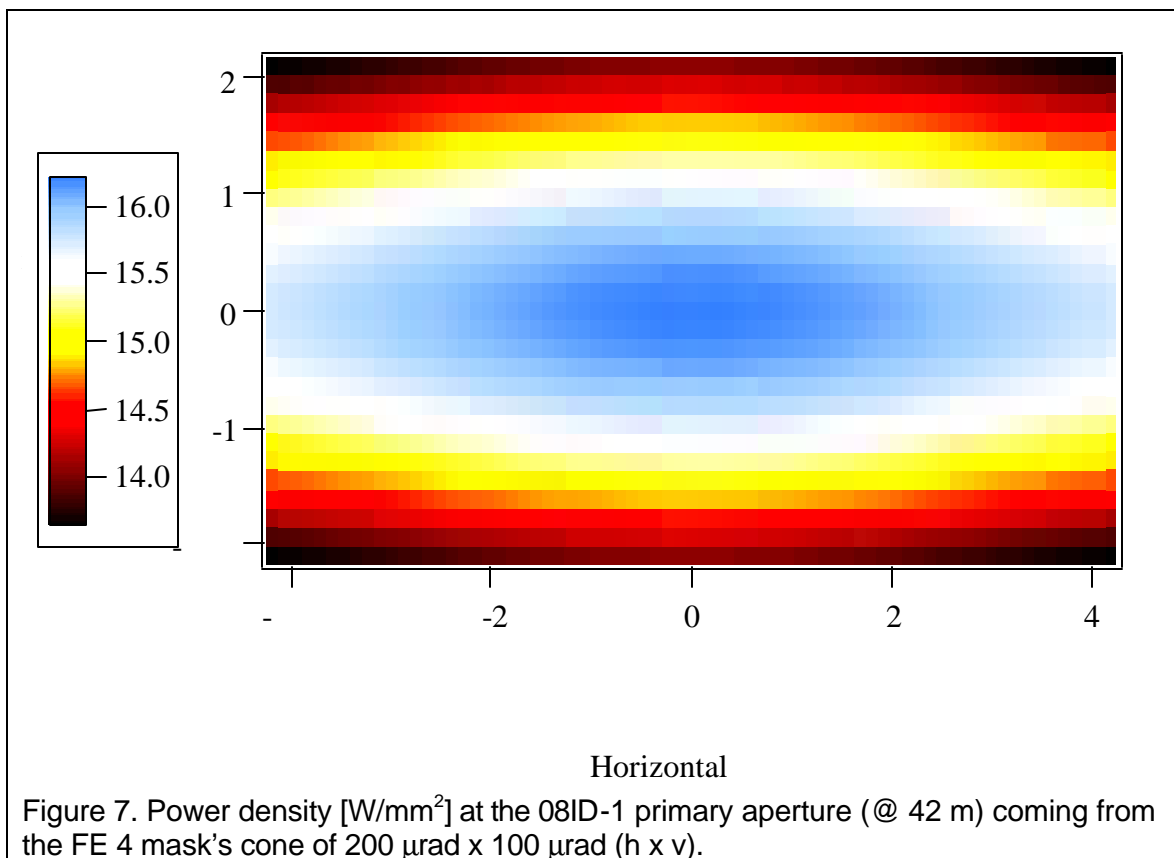
- 1.61.30.20.A Shielding and Personnel Safety Systems
  - 1.61.30.20.A .1 First Optics Enclosure
  - 1.61.30.20.A .2 White Beam Transport
  - 1.61.30.20.A .3 Monochromator Enclosure
  - 1.61.30.20.A .4 Guillotine shield & beamline downstream support
  - 1.61.30.20.A .5 Experiment Enclosure
  - 1.61.30.20.A .6 Bremsstrahlung Shielding
  - 1.61.30.20.A .7 Photon Shutter
  - 1.61.30.20.A .8 Personnel Safety System
  - 1.61.30.20.A .9 Oxygen Deficiency Monitors
- 1.61.30.20.B Photon Beamline Optics
  - 1.61.30.20.B .1 Primary Aperture
  - 1.61.30.20.B .2 Monochromator
  - 1.61.30.20.B .3 Vertical Focusing Mirror
  - 1.61.30.20.B .4 Photon beam monitors
- 1.61.30.20.C Vacuum and Photon Beam Transport
  - 1.61.30.20.C .1 Pumps and controllers
  - 1.61.30.20.C .2 Gauges
  - 1.61.30.20.C .3 Valves and controls
  - 1.61.30.20.C .4 Photon beam pipes
  - 1.61.30.20.C .5 Spools, crosses, hardware, bake-out equipment
  - 1.61.30.20.C .6 Bellows

- 1.61.30.20.C .7 Electrical Feedthroughs
- 1.61.30.20.C .8 Windows
- 1.61.30.20.C .9 Support stands
- 1.61.30.20.D Utilities
  - 1.61.30.20.D .1 Cable trays and supports
  - 1.61.30.20.D .2 Cooling DI water
  - 1.61.30.20.D .3 Service connections for enclosures
  - 1.61.30.20.D .4 Fore vacuum pumps & ventilation
  - 1.61.30.20.D .5 Compressed gas for valve control
- 1.61.30.20.E Photon beamline instrumentation & control
  - 1.61.30.20.E .1 Motor control
  - 1.61.30.20.E .2 Control computer
  - 1.61.30.20.E .3 VME crate (if needed)
  - 1.61.30.20.E .4 19 inch racks
  - 1.61.30.20.E .5 Detector electronics
  - 1.61.30.20.E .6 PLC
  - 1.61.30.20.E .7 Robot Interface
- 1.61.30.20.F Endstation Instrumentation
  - 1.61.30.20.F .1 Guard slits
  - 1.61.30.20.F .2 Goniostat
  - 1.61.30.20.F .3 Simple  $\phi$  axis with x, y, z translation or  $\chi$  stage
  - 1.61.30.20.F .4 Shutter/filter assemblies
  - 1.61.30.20.F .5 Beam stop & positioner
  - 1.61.30.20.F .6 CCD-detector and support
  - 1.61.30.20.F .7 Fluorescence detector
  - 1.61.30.20.F .8 Sample alignment & cooling
  - 1.61.30.20.F .9 Robot
- 1.61.30.20.G Data Acquisition and Data Processing
  - 1.61.30.20.G .1 Computer
  - 1.61.30.20.G .2 Data archiver
  - 1.61.30.20.G .3 Network equipment
  - 1.61.30.20.G .4 Interface electronics
  - 1.61.30.20.G .5 Beamline control software
  - 1.61.30.20.G .6 Data acquisition software
  - 1.61.30.20.G .7 Data processing software

1.61.30.20.G .8 Operating systems, etc.

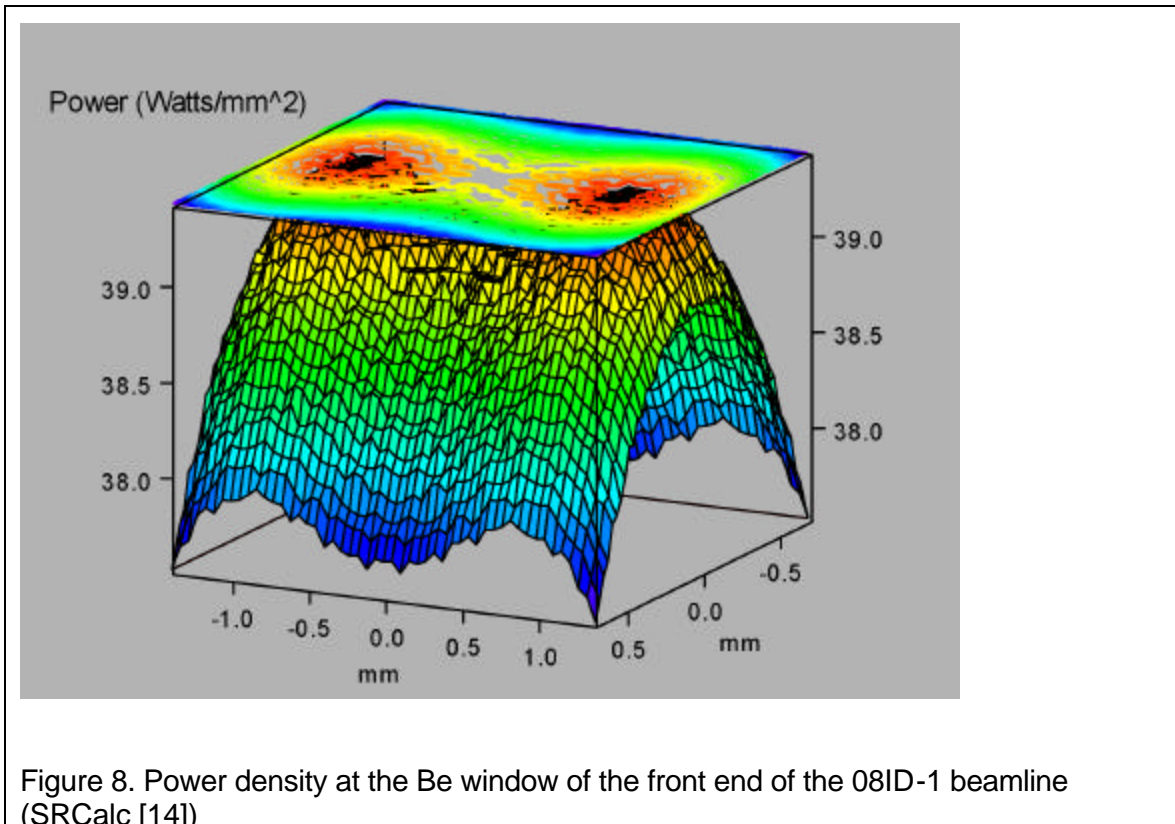
## 7.0 THERMAL ENGINEERING

Heat loaded components – primary aperture, photon absorber – are similar in design to those at the SBC, BioCAT and SER-CAT, have been reviewed by APS and proven to be adequate. The SGU of the CMCF will produce similar flux as the undulator A at APS, but the total power of the undulator A is 5.3 kW with a  $58 \text{ W/mm}^2$  power density at the primary mask (at 52m) while the CLS SGU undulator will have 4.0 kW and  $16.4 \text{ W/mm}^2$  (at 42 m) (Fig. 7), respectively.



We will use essentially the same first crystal of the monochromator as the BioCAT and SER-CAT design. The  $\text{LN}_2$ -cooled monochromator crystal has been used at the BioCAT for several years.

Although the beamline is designed to be UHV compatible and will be operated eventually in a windowless mode using differential pumping, initially a Be window will be used. With the Be window in place and CLS 2008 conditions (500 mA) the power density on the 0.5 mm window will be approximately  $40 \text{ W/mm}^2$  (Fig. 8).



## 8.0 RADIATION COMPATIBILITY OF MATERIALS

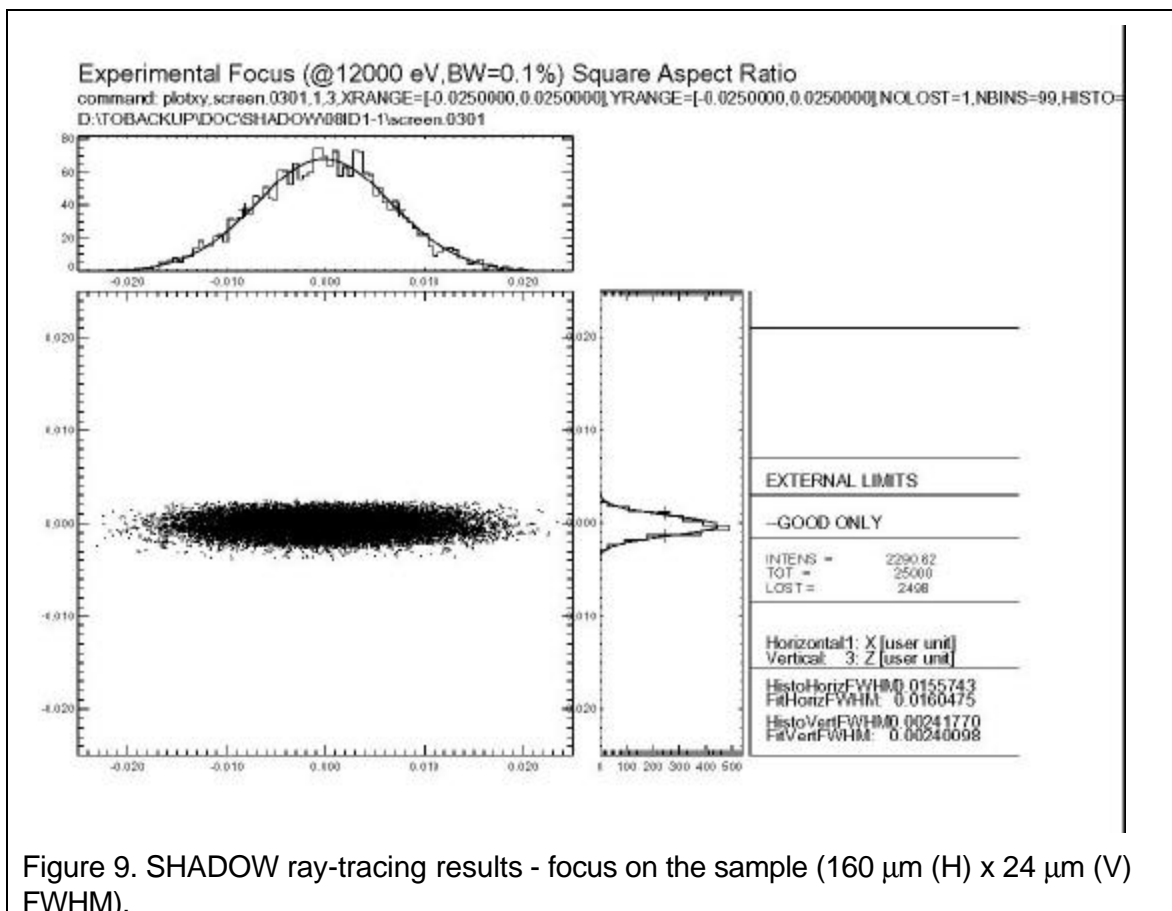
Materials used in high radiation areas are stainless steel, aluminum, OHFC copper, and some radiation resistant plastics. No Teflon or fluorinated hydrocarbons are exposed to high levels of radiation. SBC has been operating without a commissioning window for more than 1 year and the RGA scans show acceptable levels of contaminations.

## 9.0 SHADOW RAY-TRACING

The ray-tracing for the 08ID-1 beamline was done in SHADOW [15, 16] and the sample focus is shown in Figure 9. Calculations were done with slope errors included (rms tangential slope error of  $1.0 \mu\text{rad}$  and rms sagittal slope error of  $25 \mu\text{rad}$ ). The location of the components and demagnifications are shown in Table 5.

**Table 5. Location of the optical components from the center of the 08 straight section**

Component	Location [m]
Center of SGU	-0.955
FE aperture (2.78 mm x 1.39 mm)	12.965
Primary aperture (6.0 mm x 2.0 mm)	40.842
First crystal of Si(111) monochromator	42.444
Second crystal of monochromator at 12 keV	42.534
Mirror	44.613
Specimen	49.462
Horizontal magnification	0.160 – 0.183
Vertical magnification	0.106 – 0.128



## 10.0 SPARE PARTS

The beamline needs two extra sets of Si(111) and Si(220) crystals for the double crystal monochromator, and an extra mirror substrate. The other spare parts will be motor controllers and amplifiers.

## 11.0 REFERENCES

1. CMCF 08ID-1 Beamline – Technical Specifications 6.8.77.1 Rev. 0
2. <http://www.sbc.anl.gov/>
3. I. Ivanov, G. Rosenbaum, J. Chrzas, R. Fischetti, C. U. Segre, L. D. Chapman, "A Robust Cryogenic Crystal Design in Use at the APS," Synchrotron Radiation Instrumentation: Eleventh US National Conference, P. Pianetta et al., eds., 521, American Institute of Physics, (2000) pp. 271-275.
4. Photon Port Allocation - CLS Design Note 6.2.1.1 Rev. A
5. CLS - Preliminary Design Report 6.2.25.4 Rev. A
6. CLS Front Ends Design Notes - CLS 6.2.26.2 Rev. A
7. CLS High Vacuum Design Specifications 8.4.33.1 Rev 2.
8. CMCF 08ID-1 Shielded Enclosure Requirements - Design Note 6.2.77.1 Rev. A
9. CMCF 08ID-1 Preliminary Safety Report – CLS 6.2.77.3 Rev. A
10. O. Chubar, P. Elleaume, SRW, v3.7. Copyright ESRF 1997-2000.
11. Alkire, R.W, Rosenbaum, G., Evans, G., "Design of a vacuum-compatible high-precision monochromatic beam-position monitor for use with synchrotron radiation from 5 to 25 keV" *J.Synchrotron Rad.* (2000). **7**, 61-68.
12. Control System Technical Specification – CLS 7.4.39.1.
13. Electronics Development Procedure CLS 7.1.39.3 Rev. 0.
14. R. Reininger, SRCalc v. 1.2.1, 2001, <http://www.sas-rr.com/>
15. M. Sanchez del Rio, R.J. Dejus, X-ray Oriented Programs 2.0, <http://www.esrf.fr/computing/scientific/xop/>
16. C. Welnak, G.J. Chen and F. Cerrina, (1994), SHADOW: a synchrotron radiation X-ray optics simulation tool, Nucl. Instr. And Meth. A347, 344-347 SHADOW VUI, v 1.0, <http://www.esrf.fr/computing/scientific/xop/shadowvui/>

## 12.0 LIST OF DRAWINGS

1. Beamline general arrangement: 08ID-1/ME/0054300 Rev. A.
2. Beamline general assembly plan view: 08ID-1/ME/0048300 Rev. A.
3. Synchrotron Ray-tracing (horizontal) diagram: 08ID-1/ME/0054530 Rev. A
4. Synchrotron Ray-tracing (vertical) diagram: 08ID-1/ME/0054520 Rev. A
5. Beamline Optical PFD: 08ID-1/PFD/0054601 Rev. A.
6. Beamline Vacuum PFD: 08ID-1/PFF/0054611 Rev. A.
7. Beamline Process & Instrumentation Diagram: 08ID-1/PID/0054650 Rev. A.
8. Beamline Process & Instrumentation Diagram: 08ID-/PID/0054651 Rev. A.
9. Beamline Process & Instrumentation Diagram: 08ID-1/PID/0054652 Rev. A.
10. Beamline Cooling Water PID: 08ID-1/PID/0054621 Rev. A.
11. Beamline Pneumatic PID: 08ID-1/PID/0054631 Rev. A.
12. Beamline Gases PID: 08ID-1/PID/0054641 Rev. A.
13. Downstream Support Guillotine Shielding: 08ID-1/ME/0054100 Rev. A.
14. Bremsstrahlung Ray-tracing (horizontal) diagram: 08ID-1/ME/0054510 Rev. A
15. Bremsstrahlung Ray-tracing (vertical) diagram: 08ID-1/ME/0054500 Rev. A
16. Bremsstrahlung Collimator 1: 08ID-1/ME/CLM/0054150 Rev. A
17. Bremsstrahlung Collimator 2: 08ID-1/ME/CLM/0054144 Rev. A
18. Ion pump stand #2/Bremsstrahlung collimator 1: 08ID-1/ME/SPT/006372 Rev. A
19. Bremsstrahlung Collimator 3/Stop: 08ID-1/ME/CLM/0054160 Rev. A
20. Photon Shutter: 08ID-1/ME/BDP/0054700 Rev. A
21. Beamline Personnel Search Plan: 08ID-1/ME/SFY/0056725 Rev. A
22. Rosenbaum-Rock Monochromator Assembly: 08ID-1/ME/MNC/0055900 Rev. A
23. Monochromator - Cryo-crystal: 08ID-1/ME/MNC/0054550 Rev. A.
24. Monochromator - Second crystal: 08ID-/1ME/MNC/0054555 Rev. A
25. Monochromator - Thermal stabilization: 08ID-1/ME/MNC/0055925 Rev. A
26. Mirror assembly: 08ID-1/ME/MIR/0055400 Rev. A
27. Mirror substrate: 08ID-1/ME/MIR/0055450 Rev. A
28. Goniometer: 08ID-1/ME/0054800 Rev. A (sheets 1 & 2)
29. Guard slits: 08ID-1/ME/0055800 Rev. A
30. Beam stop positioner: 08ID-1/ME/0055700 Rev. A