Description of the subject of the order

X-ray optics section for the small-angle X-ray scattering SMAUG beamline

The purchase is carried out as part of the investment project *Construction of an experimental beamline for research using small angle X-ray scattering* financed by the Ministry of Science and Higher Education (IA/SP/564156/2023).

Table of Contents

1. General description of the purpose of SMAUG beamline

The subject of the order is the design, construction, delivery and installation of the full X-ray optics section of SMAUG beamline, operated in the hard X-ray energy range from bending magnet (BM02) of "SOLARIS" National Synchrotron Radiation Centre, Jagiellonian University (Krakow, Poland). SMAUG beamline is constructed by Adam Mickiewicz University in Poznań, Poland (UAM). In detail, this order will include the following main components of SMAUG beamline: a complete X-ray optics system receiving the synchrotron radiation beam from the bending magnet source (preliminary formed in the Front End section), and forming it into the collimated and focussed beam characterised by physical parameters expected for the SAXS (small angle X-ray scattering) end station. The Front End section is a scope of separate tender procedure and will be installed by SOLARIS' engineers. The installation of the beamline components will be performed by Contractor employee under supervision of Ordering Party and SOLARIS teams.

Full scope of the order, general list of proposed components and preliminary layout is presented in chapter 8.

The SMAUG beamline is designed for small angle X-ray scattering (SAXS) experiments using synchrotron radiation in the energy range approximately from 6 to 15 keV. The SAXS end station is intended to be used for small angle scattering experiments, mostly on solutions of biomacromolecules (BioSAXS) performed in the "high-flux" data collection mode and for high energy resolution SAXS measurements (including anomalous scattering experiments) as well.

The subject of the order includes all functional components to build an optical part of beamline and connect this equipment to end station (a separate order, which will be finalised in December 2024) to complete a full operational beamline.

List of abbreviations:

PDR - *preliminary design review*
FDR - *final design review*
FAT - *factory acceptance test/tests*
SAT - *site acceptance test/tests* (in SOLARIS NSRC)
BM - *bending magnet*

SDD - *sample to detector distance*

2. General description of SMAUG beamline

The SMAUG beamline is to be installed at bending magnet (double-bend achromat, magnetic field 1.31 Tesla) – section 02 of SOLARIS storage ring. The detailed source parameters can be found in the Appendix SOURCE. The expected technical parameters of SMAUG beamline with SAXS end station include the use of two X-ray optics modes, implemented in DCM/DMM system - the first one with high energy resolution (HR - high resolution mode) and the second one optimized to obtain high intensity of synchrotron radiation (HF - high flux mode).

The expected beam size (with fully open slits) is approximately 200 x 200 μm in the SAXS end station. However, alternative design and better focusing parameters can be proposed also by the Contractor. The expected beam divergence at the entrance of the end station is about 0.2 mrad.

For the SAXS end station, the expected X-ray photon flux, calculated for the photon energy of 10 keV, should be above 10^{10} photons/s for the **HR mode** (DCM Si(111)) and up to 10^{12} photons/s for the **HF configuration** (double multilayers).

In the high resolution mode, the energy resolution of synchrotron radiation should be about 1.4×10^{-4} ($\delta E/E$), while in the high flux mode the energy resolution should be about 0.008-0.02 ($\delta E/E$).

The further description of the subject of the order presents the concept of selection and arrangement of typical optical components (mirrors, monochromator). However, the Ordering Party allows the potential Contractor to modify this concept in order to optimize the parameters of the synchrotron radiation beam formed in the optical section.

3. Time scales

In the offer, the Contractor **should clearly specify the proposed time schedule for reaching and delivering the milestones:**

- Design of the main sections of the beamline X-ray optics with all necessary calculation (ray tracing, heat loading, etc.)
- Preliminary Design Review Report (PDR)
- Design review meeting at SOLARIS
- Final Design Review Report (FDR)
- Fabrication of the beamline components (optic elements and vacuum components together with precise mechanics)
- Factory acceptance test (FAT) under supervision of Ordering Party (UAM) and SOLARIS team
- Delivery of all systems to the SOLARIS site
- Installation of the beamline system under supervision of Ordering Party (UAM) and SOLARIS team and the Final Acceptance Tests
- Training of the Ordering Party (UAM) and SOLARIS staff

It is expected that the delivery time of all beamline components should not exceed 18 months from the signing of the contract. Additional 3 month(s) should be scheduled for the assembly of the beamline on-site at SOLARIS.

All changes in the contract time scale, caused by unexpected technical problems should be introduced in written form as an Annex to the contract.

4. Description of X-ray source – bending magnet

4.1. SOLARIS storage ring parameters

SOLARIS is a 1.5 GeV storage ring based on the double-bend achromat (DBA) magnetic lattice (12 DBA cells). Electron bunches are injected from the linac (linear accelerator) at the energy ~550 keV, then they are ramped to the final energy of 1.5 GeV in the storage ring. The maximum number of bunches is 32, and the maximum current of the stored beam is 500 mA. The design horizontal beam emittance is 6 nmrad, vertical is 60 pmrad. The critical energy of the synchrotron radiation beam from the bending magnet (magnetic field of 1.31 Tesla) is approximately 2 keV. For detailed specifications see Appendix SOURCE.

Main parameters of storage ring are presented in Table 1.

Table 1. Main measured electron beam parameters in the middle of the DBA section

Quantity	Value
Emittance x	8.05 nmrad
Emittance y	65 pmrad
β_x; β_y	0.220 m; 15.78 m
Beam size σ_x; σ_y	44 µm; 31 µm
Beam div σ_x'; σ_y'	199 µrad; 3 µrad

The photon source size and divergence simulated with the parameters of the electron bunch and DBA are shown in Figure 1.

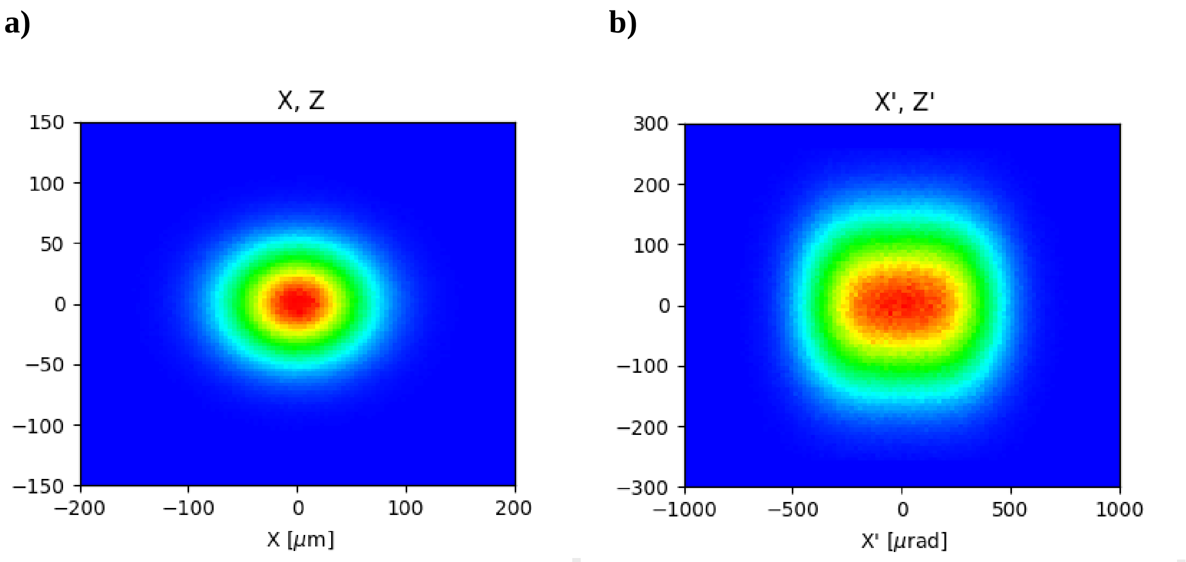


Figure 1. *Simulated source parameters of bending magnet 02 for 10-keV photons*

a) *Source size (FWHM): 100 μm × 70 μm,*

b) *Source divergence 0.75 mrad × 0.21 mrad (for horizontal beam acceptance set to 0.75 mrad) Flux at 10 keV is* 2.68×10^{11} *ph/s/0.1% bw.*

5. Technological standards at NSRC SOLARIS

5.1. Vacuum requirements

The Supplier is required to follow the requirements and standards, describing technologies and materials for UHV (ultra-high vacuum) devices in the NSRC SOLARIS and presented in guidelines for UHV-components at SOLARIS (see Appendices VAC1 and VAC2). For UHV and VHV (very-high vacuum) or HV (high vacuum) systems the requirements and standards are described in this document (Table A).

Table A

Pressure Region	Pressure Range (mbar)	Typical Leak Rate* ($mbar \cdot l \cdot sec^{-1}$)	Typical Outgassing Rate* ($mbar \cdot l \cdot sec^{-1} \cdot cm^{-2}$)
Low Vacuum	1000 – 1	10^{-2}	10^{-4}
Medium Vacuum	1– 10^{-3}	10^{-5}	10^{-7}
High Vacuum	10^{-3}– 10^{-7}	10^{-7}	10^{-9}
Very High Vacuum	10^{-7}– 10^{-9}	10^{-9}	10^{-11}
Ultra-High Vacuum	10^{-9}– 10^{-12}	10^{-10}	10^{-13}
Extreme High Vacuum	$P<10^{-12}$	$<10^{-12}$	$<10^{-15}$

According to ASTeC - Accelerator Science and Technology Centre

5.2. Mechanical requirements

The Supplier is required to follow the requirements described in the NSRC SOLARIS mechanical standards (see Appendix MECH1). Information about beam geometry and space limitations is given in the Appendices MECH2, MECH10-BM02, MECH11-BM02, MECH12-BM02, MECH13-BM02, MECH14-BM02 and FE1-BM. Guidelines in field of standard procedures of on-site alignment is provided in Appendix ALIGN. All chambers and main components should be delivered with fidualization data which allowed us for the fidualization process during installation.

5.3. Security systems PSS (PLC protection)

The security systems employed at the SOLARIS NSRC are divided into two subsystems: the Synchrotron PSS and Experimental Beamline PSS. These subsystems, namely the Machine Protection System (MPS) and the Personal Safety System, have been developed with the purpose of ensuring the safety of personnel and users within designated areas. They are designed to prevent any exposure to ionizing radiation and have the ability to halt the synchrotron operation in the event of a hazardous situation. The security systems are built on PLC controllers (programmable logic controllers) and incorporate components that are reliable, safe in the event of damage, redundant and diversified (especially the most critical parts).

The Contractor will provide guidelines for the design of security systems if it is necessary to integrate the X-ray optics system with them. All project guidelines should be provided within 2 months of accepting the overall design (FDR).

We currently have the results of radiological calculations and a conceptual design of shields, based on which and the offer for the X-ray optics section, a decision will be made about the construction of an X-ray optics hutch and integration with the NCPS Solaris PSS system.

If the integration with the PLC system is necessary, the Contractor will be responsible for furnishing a comprehensive list of devices that necessitate connection to the PLC systems, in particular electrical connection diagrams elucidating the dedicated interfaces and external connectors, along with the requisite current and voltage parameters, and other pertinent specifications. The preferred devices supported by PLC safety systems are those that accept 24 VDC as the standard voltage on external input/output interfaces.

5.4. Control systems

The Supplier is required to follow the technological requirements described in *Control System Standard for New Accelerator, Front End and Beamline Components* (see Appendix CS0) and in *Motion Control Standard* (see Appendix CS1). Detailed responsibility matrix for control systems can be provided by Ordering Party on request.

5.5. Cooling water

The Contractor is obliged to comply with the SOLARIS NSRC requirements regarding the cooling water standards, as described in Appendix WAT-CW1.

The Contractor should present the requirements of the X-ray optics section regarding the use of the cooling water infrastructure, if it is planned to be used during the execution of the order. The presentation of this data is expected no later than the Preliminary Design Review (PDR) meeting to ensure that they are considered during the design phase of the optics hutch.

5.6. Compressed air

The Contractor is obliged to comply with the SOLARIS NSRC requirements regarding the compressed air standards, described in Appendix WAT-CW1.

The Contractor should present the requirements of the X-ray optics section regarding the use of compressed air infrastructure (continuous consumption, maximum instantaneous consumption). The presentation of this data is expected no later than the Preliminary Design Review (PDR) meeting to ensure that they are considered during the design phase of the optics hutch.

6. Location of the SMAUG beamline in the experimental hall of NSRC SOLARIS

6.1. Detailed location of SMAUG beamline

The SMAUG beamline will be placed in the new (extended) experimental hall of NSRC SOLARIS. The detailed location of the beamline on the experimental hall design is presented in Figure 2. For details, please see Appendix MECH10-BM02, MECH11-BM02 and MECH15-BM02.

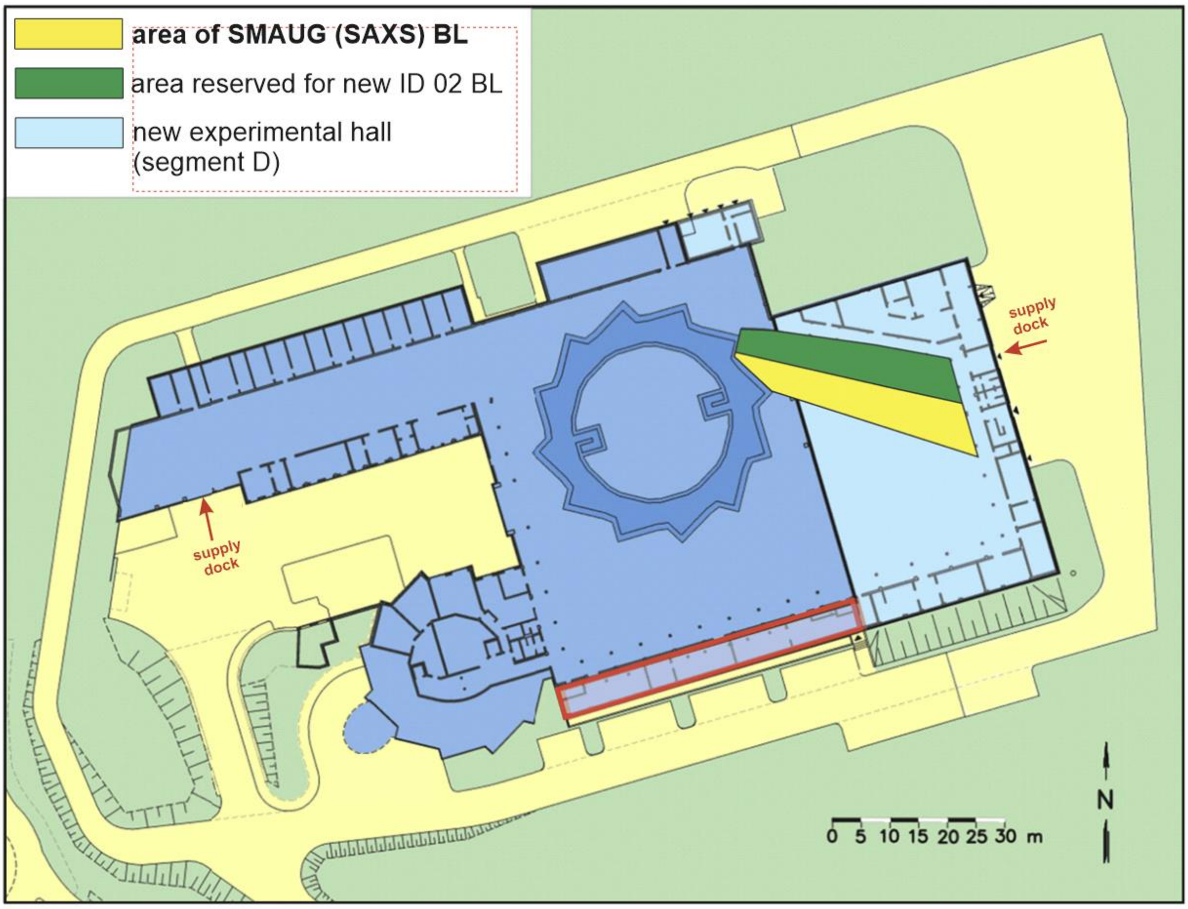


Figure 2. *Experimental hall (extended part) of NSRC SOLARIS with marked schematically region (yellow) designated for installation of the SMAUG beamline.*

6.2. Technological parameters of media available for the beamline

6.2.1. Cooling water

There is a cooling water system available in the experimental hall for cooling the optical elements and other components of the SMAUG beamline. The Contractor should specify the type, parameters and proposed location of the connection to the local cooling water network. For details related with SOLARIS standards please refer to the Appendix WAT-CW1. Schematic representation of the local cooling water network (access to cooling water) in the experimental hall of NSRC SOLARIS and appropriate technological data at the Contractor's request, may be made available.

6.2.2. Compressed air

Compressed air systems for the SMAUG beamline were installed in the new part of the experimental hall of NSRC SOLARIS. The Contractor should specify the basic technological parameters, type and location of the connection to the compressed air network. For details related with SOLARIS standards please refer to the Appendix WAT-CA1. At the Contractor's request, appropriate technological data may be made available.

6.2.3. Power Supply

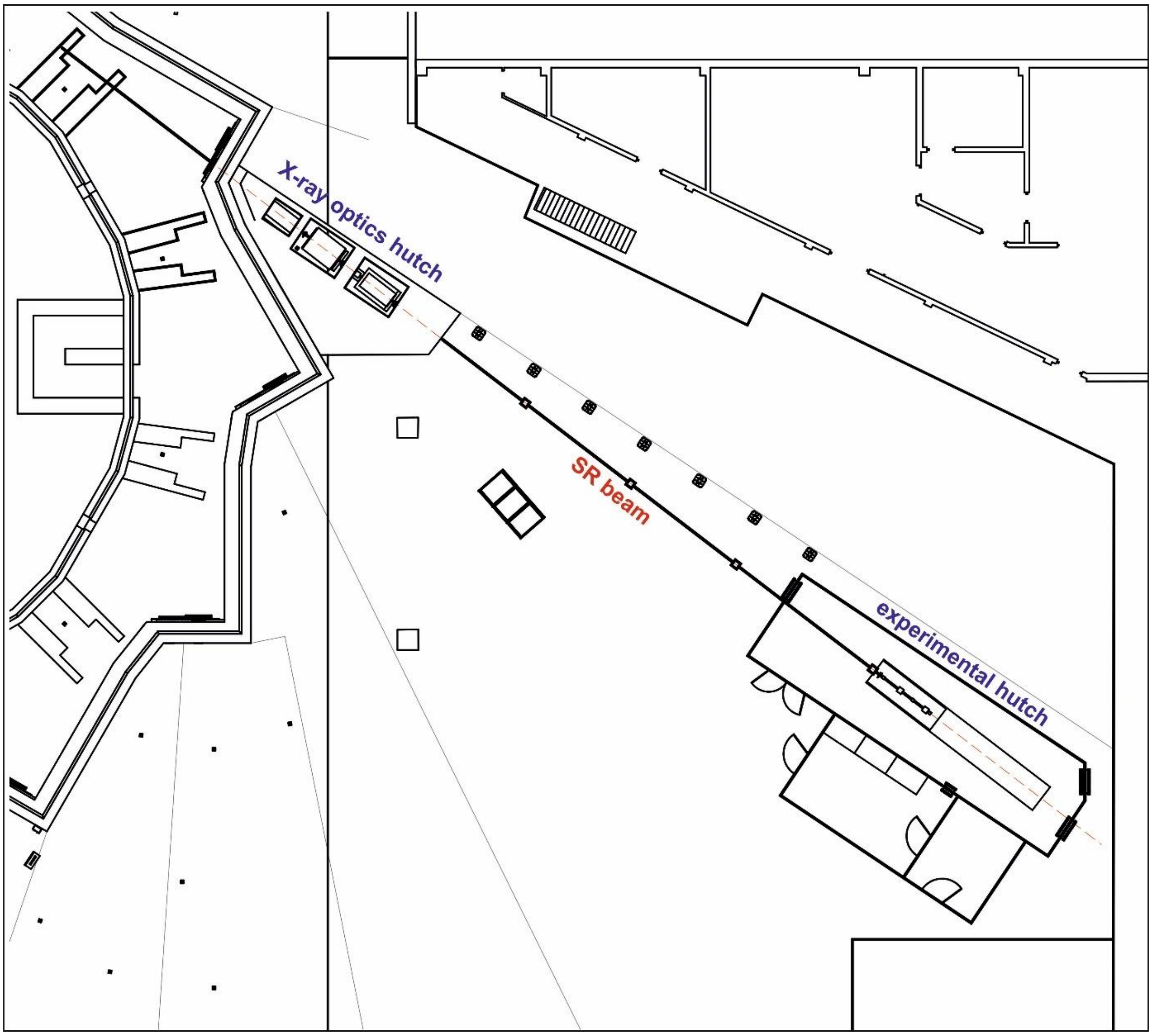
Ordering Party provides electricity supply with a voltage 230/400 V and frequency 50Hz. To connect devices, use a 16 A type E plug for 230 V voltage and 32 A 5P CEE plug for 400 V voltage. Due to short distance from transformer, any overcurrent protection MCB, should have a short-circuit strength of 10 kA.

7. Beam orientation

7.1. Mechanical requirements and site constrain

The optical components will be installed in the radiation hutch of the beamline BM02 of the NSRC SOLARIS. For a preliminary design of the X-ray optics hutch and space constrain see Appendix MECH15-BM02. The STEP file with optical hutch design can be available from Ordering Party on request.

a)



b)

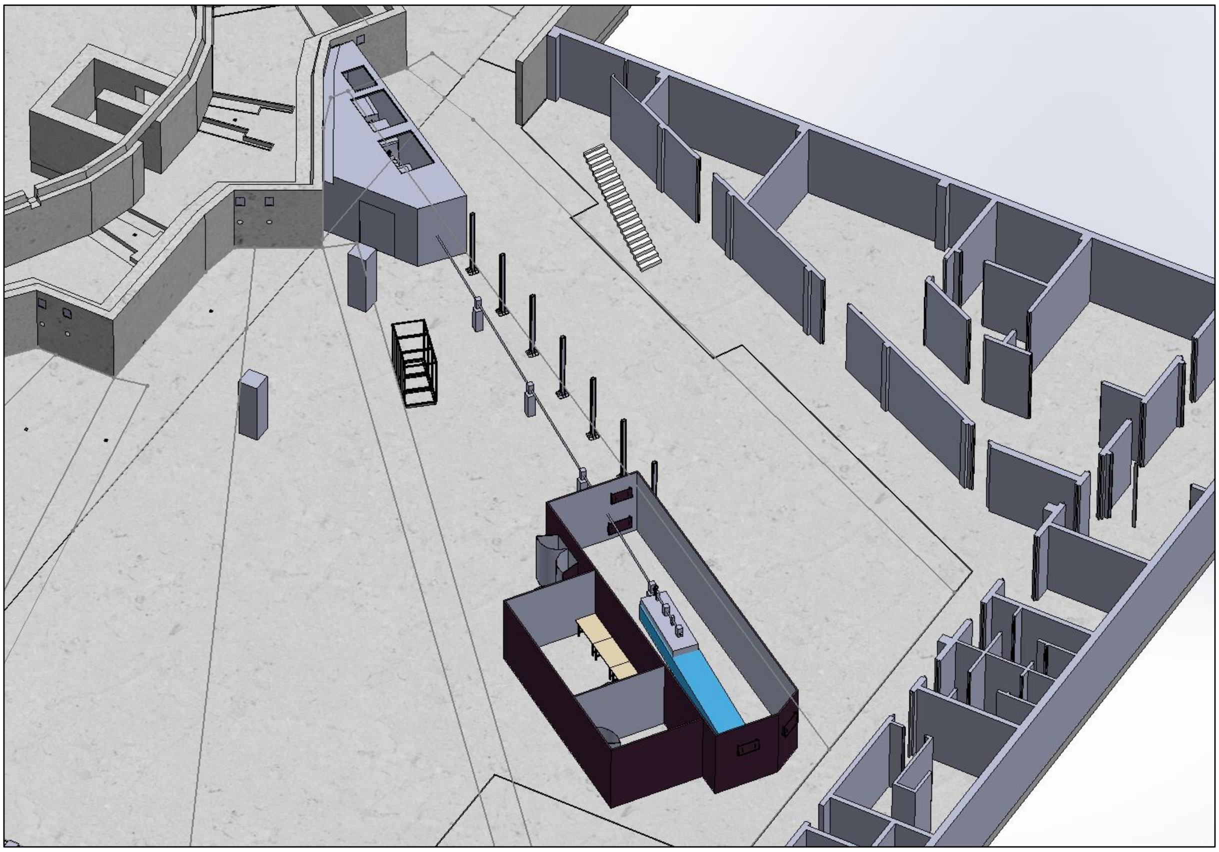


Figure 3. *Conceptual design of the SMAUG beamline – a) X-ray optics hutch with predicted location of optical components and experimental (end station) hutch. In the X-ray optics section the position of main components is marked together with dedicated holes in the roof structure, b) 3D representation of full SMAUG beamline with XEUSS 3.0 UHR located in the experimental hutch*

The final design of the hutch, including holes in the ceiling for installation of the optical elements will be prepared by SOLARIS after the detailed design of the complete optical system by the Contractor. The preliminary location of SMAUG optical hutch and experimental hutch is presented in Figure 3, while the conceptual design of X-ray optics hutch in Figure 4.

The nominal height of the photon beam axis is z_{WHITE}=1300 mm above the floor level. The photon beam from the BM is horizontal and parallel to the floor. The general SOLARIS standards and practices related with supports and mechanical engineering are described in Appendix MECH1 and should be followed during the design and installation phases. Exemplary vibration characteristics of floor in experimental hall is presented in Appendix VIB1.

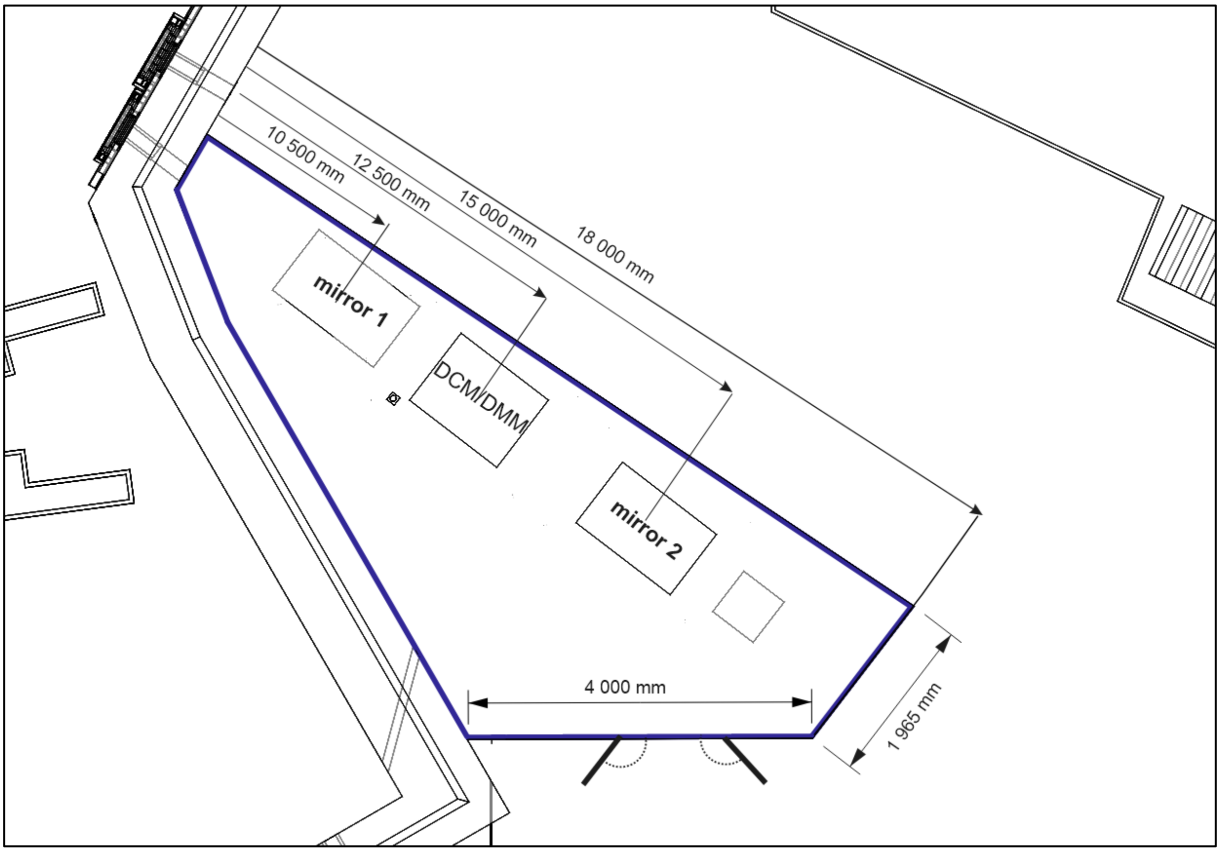


Figure 4. *Preliminary conceptual design of the SMAUG optical hutch with predicted location of main optical components and openings in roof for transport of these components.*

7.2. Alignment procedures

For the alignment of elements of the optical system during installation, number of threaded holes made according to SOLARIS standard (Appendix ALIGN) has to be prepared, as support for Leica RRR (1.5-inch diameter) reflectors. The required number and location of the fiducial points must be agreed upon with SOLARIS. After the agreement, the Contracting Authority (SOLARIS) will send the sockets to the Contractor for mounting and fiducialization. The reference points must be referenced to the photon beam plane and the axis within 0.1 mm and the angular accuracy of less than 0.2 mrad. The vacuum vessels should be supported by a special girder allowing the possibility to correct position in all directions. The support system must allow for alignment of the vessels to the accuracy of at 0.1 mm within a range of at least ± 15 mm vertically and ± 15 mm horizontally and longitudinally. SOLARIS will provide a common assembly tool as agreed with the Contractor. The elements of the system must be equipped with transportation loops to fit the vessels with the crane to its position in the hutch.

The crane (of 8 tons capacity) provides 4 m as the maximum height of the crane hook above ground.

8. Scope of the order, general list of components and preliminary layout

In this tender, the Ordering Party expects the Contractor to design, construct, deliver and install a complete X-ray optics section for SMAUG beamline, located between the Front End section and the SMAUG beamline end station along with the synchrotron radiation transfer line. The scope of the order therefore includes all X-ray optics components and all diagnostic beamline components, beam forming systems (slites), beam shutter, etc. The order must also include all necessary vacuum components (valves, pumps, transfer tubes, vacuum bellows, etc.). The Contractor shall also supply cables entering and leaving the vacuum system, electrical connectors placed on a common junction box (patch panel) for each set of devices. It is Supplier responsibility for the design of the internal wiring of a given device. The Contractor shall deliver power supplies and controllers (for ion pumps, vacuum gauges) compliant with the SOLARIS standard. The proposed scheme of vacuum sections is presented in Figure 5. The Ordering Party has provided for a minimum number of 5 vacuum sections to ensure the required vacuum parameters. However, the Ordering Party leaves a proposal for the number of vacuum sections to the Contractor.

The Ordering Party and NCPS SOLARIS will provide IcePap motion controllers, which are a standard in NCPS SOLARIS. Additionally, the Ordering Party will perform full cabling on its own (low-current, power supply and IT systems for the SMAUG beamline). Detailed technical guidelines will be expected from the Contractor in this regard.

A graphical representation of the proposed arrangement of the SMAUG beamline components, including the division into the proposed vacuum sections, is presented in Figure 5 and summarized in Table 2.

The following sections of this technical description contain detailed technical requirements characterizing the main optical components of the SMAUG beamline.

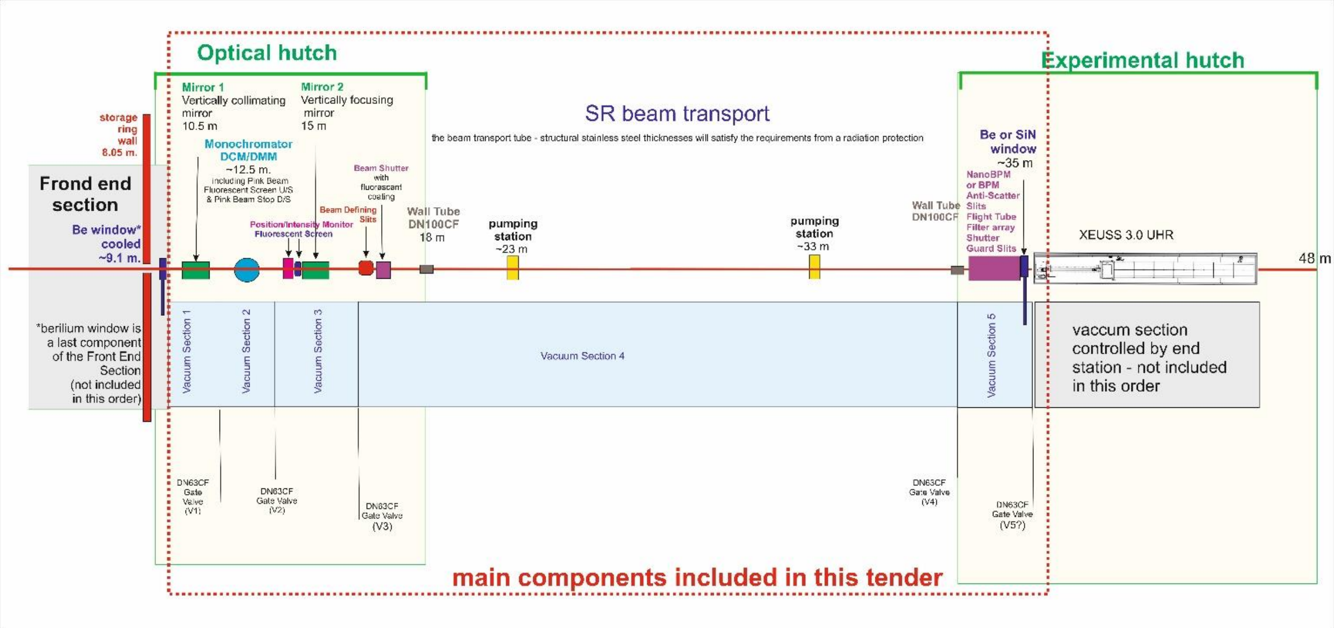


Figure 5. *Graphical representation of the proposed scope of the order. The Contactor can propose in the offer the modification of the proposed here layout including location of components and number of vacuum section.*

Table 2. List of proposed components. SMAUG beamline shall comprise the following components located between Front End Section (terminated by water cooled Be window) and the endstation (XEUSS 3.0 UHR system).

Optical section part 1 – in X-ray optics hutch
Main components:
Vacuum section 1
Diagnostic fluorescent screen
Vertically collimating mirror (VCM) – *10.5 m from the source*
Gate Valve (V1)
Vacuum section 2
White beam slits (if necessary) DCM/DMM monochromator including Pink Beam Fluorescent Screen U/S and Pink Beam Stop D/S – *12.5 from the source*
Radiation collimator – according to radiation safety report (description - section 9.2.12)
Gate Valve (V2)
Vacuum section 3

Position/Intensity Monitor
Fluorescent Screen
Vertically Focussing mirror VFM – *15 m from the source*
Gate Valve (V3)
Vacuum section 4
Beam Defining Slits
Beam Shutter with Fluorescent Coating
Wall Tube, *X-ray optics hutch terminates at 18 m* (from the source)
SR beam transfer line (from 18 m to ~34 m)
Components:
Beam Tube*
Pumping station 1 (*23 m from the source*)
Pumping station 2 (*33 m from the source*)**
Optical section part 2 – in experimental hutch
Main components:
Wall Tube
Pumping cross
Gate Valve (V4)
Vacuum section 5***
BPM or NanoBPM
Filter array
Anti-Scatter Slits
Beam tube
Beam shutter
Guard slits
Be or SiN window
All standard vacuum components not listed above (eg. bellows, ion sputter pumps, gate valves, all-metal angle valves, controllers for vacuum components etc)

** The beam tube should be proposed according to radiation shielding report, which is available on the request from the Ordering Party. Lead shielded tube is not required, however the radiation shilding report prepared for this concpet is available on request.*

*** The number and position of pumping stations should be clarified during PDR.*

**** The Ordering Party leaves the order of arrangement of the optical conditioning components to be agreed with the Bidder no later than the PDR meeting.*

9. Optics for the SMAUG beamline – description of main components

The main components of the X-ray optics for SMAUG beamline (see general layout – figure 6) are:

- Vertically Collimating Mirror;
- Double Crystal/Multilayer Monochromator (DCM/DMM);
- Vertically Focusing Mirror.

Main beam shaping and diagnostics components of the SMAUG beamline are:

- Slit systems (horizontal and vertical);
- Fluorescent screens
- Position/Intensity Monitor(s)
- BPM or NanoBPM and components located in beam conditioning unit
- Fast feedback system for positioning of SR beam

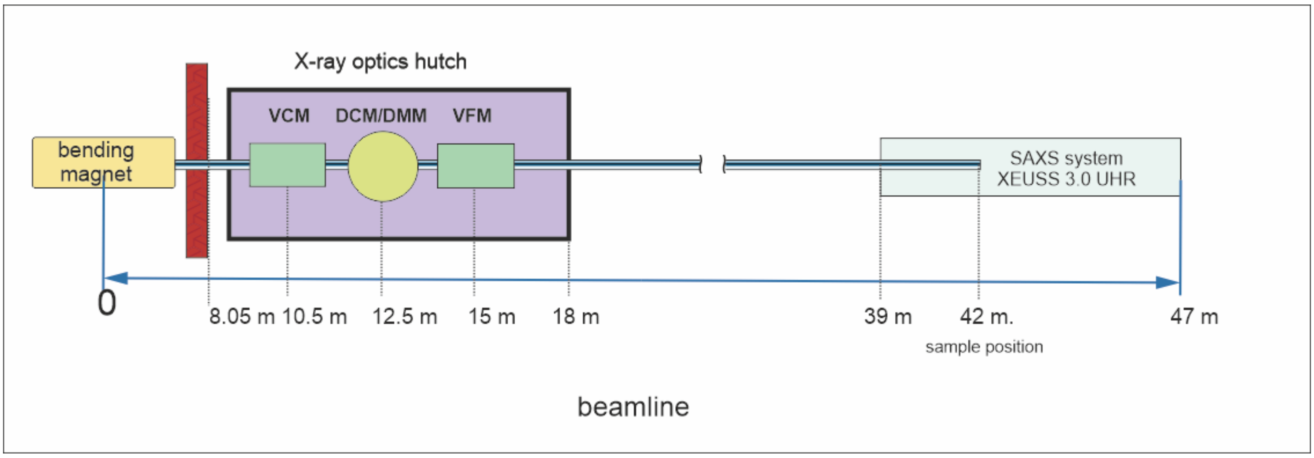


Figure 6. *The schematic layout of arrangement of vacuum chambers of main components of SMAUG beamline. BM – bending magnet, VCM - Vertically Collimating Mirror, DCM/DMM - Double Crystal/Multilayer Monochromator, VFM – Vertically Focusing Mirror, SAXS – experimental camera (SAXS system). Please note that last component of FE section terminates on 9.1 m (from source).*

The ray tracing analysis of the above concept is summarized in Appendinx_RAY-TRACING-BM02. The tested options included focal points at sample position (42 m), middle of SAXS tube (45 m) and end of the SAXS tube (48 m).

The Contractor is encouraged to comment on any aspect of this specification and to identify possible modifications that could lead to either improved parameters or reduced cost without compromising the performance specification.

The Ordering Party allows the potential Contractor to modify this concept in order to optimize the parameters of the synchrotron radiation beam formed in the optical section.

The distance from the source to the sample stage (position of the goniometer head / the sample position in the BioSAXS cell) is expected to be c.a. 42 m from the source.

9.1. Vertically Collimating Mirror (VCM)

The main roles of the VCM are:

- to take the initial heat load of the white beam from the BM
- cut the photons of the energies higher than ~15 keV out;
- collect the flux of the DBA white beam make the reflected rays parallel in the vertical direction.
- focus the reflected rays horizontally in the middle of SAXS tube (45 m from the source) in the mid-range of angular working position

This will allow to achieve the maximum energy resolution of the Double Crystal Monochromator given by the intrinsic Darwin width of the Si(111) reflection. It should be oriented horizontally – reflecting the photon beam downwards (see Figure 7). The working angle of the mirror should be adjustable, that the horizontal focal point should move between the sample position (~42 m) and the far-end of the SAXS tube (~47 m).

9.1.1. Definition and references

The diagram shown in Figure 7 indicates the relationship of the various degrees of freedom referred to throughout this specification. These are shown with respect to the path of the beam.

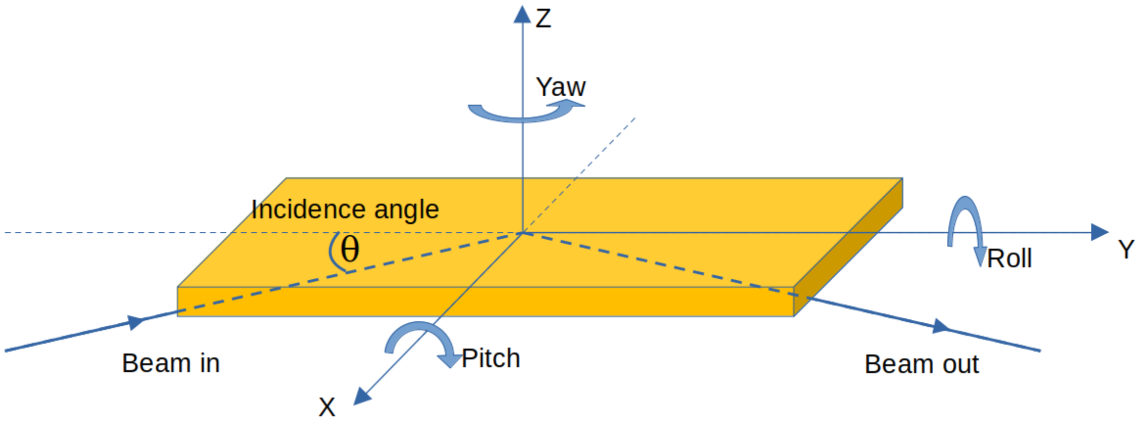


Figure 7. *Nomenclature of the VCM motions.*

The mirror should be covered with rhodium deposited on a silicon substrate, and enable operation up to incidence angle of θ_{MAX}=5.2 mrad (to eliminate photons of energies higher than ~15 keV). Mirror parameters are listed in Table 3.

Ordering Party does not exclude that the 1st mirror can be bended, this can be proposed by Contractor.

Table 3. Required parameters of the VCM.

Parameter	Specification
Operating position	Vertically Collimating Mirror
Nominal working incidence angle	5 mrad
Location	10.5 from source
Max. Incidence angle	~5.2 mrad
Stripe	Rh
Active area of single stripe	~ 850 × 20 mm
Blank dimension	~ 900 mm
Shape	toroidal cylinder (with optional bending), *however Contractor can propose other shape (eg. cylinder) with justification*
Radii of curvature	Depends on the location, TBA*
Slope error	< 1.0 µrad RMS
Cooling	Slot-cooling or clamped side-cooling**

** Exact radii of curvature of the VCM should be calculated according to the formulas:*

Major R = 2p/sin θ, where R – radius of curvature, p – distance from the source, θ - grazing angle of the mirror. E.g. For p = 10.5 m, and θ = 5 mrad, it results in R = 4.2 km.

Minor ρ = 2pqsin(θ)/(p+q), where ρ – radius of curvature, p – distance to the source, q – distance to the focal point, θ - grazing angle of the mirror. E.g. For p = 10.5 m, q = 34.5 m and θ = 5 mrad it results in ρ = 8.5 cm

*** This concept depends on the technical properties of component proposed by Contractor.*

All details regarding VCM optics shape, dimensions and surface quality have to be presented in the Offer (if possible) with the justification of proposed values.

All metrology results regarding optics surface quality and shape errors (surface roughness, slope errors, etc.) have to be provided during Factory Acceptance Tests.

9.1.2. Cooling

The mirror can be water cooled, however the direct water-to-vacuum joints are not permitted. Details of the cooling system are left to the Contractor to design, and the exemplary cooling scheme (or reference) should be presented in the offer. NSRC SOLARIS standards of cooling water and water system are described in Appendix WAT-CW1 and should be followed during the design phase. Separate cooling scheme (cooling using dedicated separate chiller) can be proposed by Contractor.

9.1.3. Diagnostic fluorescent screen

For the diagnostics of the incoming photon beam position, a fluorescent screen should be fitted to the front of the optical component. The screen should be coated with a phosphor coating (or other fluorescent screen can be proposed) that will be illuminated by the incident beam. Therefore, a viewport in the vacuum vessel should be planned in line with the screen and should be used by the customer to fit their own CCD camera (cameras from the series Basler Ace, e.g. acA1280-60gm or compatible are the standard devices used in NSRC SOLARIS).

9.1.4. Mirror mechanism

Motorization mechanism of the mirror assembly should ensure to control pitch, roll, yaw, horizontal translation and height. All movements should be driven by a two-phase bipolar stepper motor. The jacks should be protected from overtravel by limit switches. Positional feedback should be provided by encoders (see Appendix CS1 regarding SOLARIS requirements for the motorization).

The specific motions properties should be presented by the Contractor in the offer.

9.1.5. Support plinth/girder

The support structure a massive block of granite should be as a seismic mass for the system. It should be bolted to the facility's floor via a grouted steel baseplate and support the mechanical adjustment stages of the optics.

Manual adjustment should be also planned (for use at the time of installation) to allow x, y, z and angular adjustment of the mirror assembly via jacking bolts (or "push blocks") on the grouted baseplate (see ALIGN for examples, required ranges and precision).

9.1.6. Vacuum vessel

All mechanisms inside the UHV space shall use UHV compatible materials with dull polished or machined finish, which shall be cleaned according to the SOLARIS vacuum standards. The SOLARIS vacuum standards are described in Appendices VAC1 & VAC2. UHV compatible joining methods (welding, vacuum brazing etc.) shall be used throughout. Lifting points shall be planned on the vessel lid.

Vacuum requirements for VCM shall be compatible with UHV or at least VHV standard:

- Base pressure $\leq 5 \cdot 10^{-10}$ mbar
- Leak rate level (sum of all leaks) $\leq 5 \cdot 10^{-10}$ mbar·l/s
- RGA criteria: the sum of the partial pressures of masses above mass 44 up to 100, is less than 5 x 10^{-3} of the total pressure in a leak-free system with a total pressure below $1 \cdot 10^{-9}$ mbar
- Outgassing rate $\leq 1 \cdot 10^{-11}$ mbar·l·sec^{-1}·cm^{-2} (only if this procedure can be applied for the particular technical solution proposed by Contractor)

The vessel baseplate shall be fitted with points for mounting fiducials for alignment during installation in accordance with SOLARIS requirements (described in Appendix ALIGN).

A list of planned vacuum ports must be presented in the offer together with specification and justification of the purpose (e.g. beam inlet, beam outlet, ion pump, RA valve for roughing pump, viewports, gauges, cooling and electrical feedthroughs, mirror support, loading and maintenance etc.). The exact number, specification, justification and positioning of these ports must be discussed during the design phase and approved before manufacture commences.

General requirements of the vacuum standards at NSRC Solaris are presented in Appendix VAC1 & VAC2.

9.1.7. Motors and Encoders

All motions will be driven by two-phase stepper motors. Use of *in-vacuum* motors should be agreed with NSRC SOLARIS before the Final Design (see Appendix CS0). Ordering Party allows use of piezoelectric actuators for particular technical solutions (only if it is necessary).

All motions should be fitted with encoders (see Appendix CS1 regarding standards and practices used at NSRC SOLARIS for the motorization).

9.1.8. Controls Interface Panel

Cables from the instrument should run form patch panel to the control panel or rack on the side of the Local Controls Cabinet from which the field cables connect and where cables should be available.

9.2. Double Crystal/Multilayer Monochromator (DCM/DMM)

The monochromator should be a hybrid or tandem device i.e. DCM and DMM, should be placed in a single vacuum vessel. The monochromator should contain 2 sets of diffractive optics – a silicon Si(111) single crystal set and a pair of multilayer optics - to cover both high energy resolution and high flux configurations. Precise arrangement and mechanism of optics motion during energy change and interchanging the crystals and multilayers in the photon beam is left to the design of the Contractor. The Si(111) crystals working range should cover the photon energies ~6-15 keV, and the multilayers (two separate double multilayers) should cover ~6-14 keV at a relative energy bandwidth approximately 0.8 – 2 %. A lateral translation should be used to select the relevant stripe. **The Contracting Authority expects that the Contractor will present a specific proposal of a multi-layers materials that will be used for the**

construction of the multi-layer monochromator segment, with justification (Multilayer Mirrors ML1, ML2, ML3, ML4; for details see section 9.2.11).

DCM/DMM should accept the full incident beam size given by the VCM upstream.

The optical components should be water cooled. Calculation of the power load on the optics should be provided.

Two reflecting optical elements should be antiparallel to each other. The desired photon energy is selected by rotating the complete set, thereby varying the Bragg angle (θB), whilst keeping the optical pairs parallel to one another. The first optics can be brought into the beam by a Bragg rotation and perpendicular translation.

The beam reflects from the diffracting face of the second optics and leaves the monochromator parallel to the incident beam with a constant offset. The fixed offset of the outgoing beam is achieved via a translation of the second optics in a direction perpendicular to their diffracting surfaces.

The DCM/DMM should consist of the following subsystems:

- Primary stage: The purpose of the primary stage is to rigidly support the crystal cage and to provide the main Bragg rotation.
- Crystal Cage: The purpose of the crystal cage is to house the monochromator crystals and provide the precise 1st and 2nd crystal set translation and adjustments.
- Vacuum System: The system consists of the vessel which encloses the crystal cage, its mounting frame and various electrical, coolant and mechanical feedthroughs associated with the crystal cage.
- Monochromator Controls: The purpose of the monochromator controls is primarily to move the motion control elements of both the primary stage and the crystal cage. The only components of control system included in the scope of this tender should be those for the piezoactuators. **For control elements not meeting the NSRC SOLARIS standards for motion control (see Appendix CS1) the Contractor should provide an appropriate device server and present it in the final offer.**

A detailed description of the requirements for the monochromator subsystems is presented in the following paragraphs.

9.2.1. Pink beam fluorescent screen

Before the monochromator, a single vacuum chamber containing fluorescent screen should be attached to the monochromator vessel. Fluorescent screen should be moved either with a pneumatic actuator (IN and OUT positions) or stepper motor. The vacuum vessel should be equipped with a view port suitable to observe the fluorescent screen with a CCD camera.

9.2.2. Definitions and References

The diagram shown in Figure 8 indicates the relationship of the various degrees of freedom referred to throughout this specification. These are shown with respect to the path of the beam.

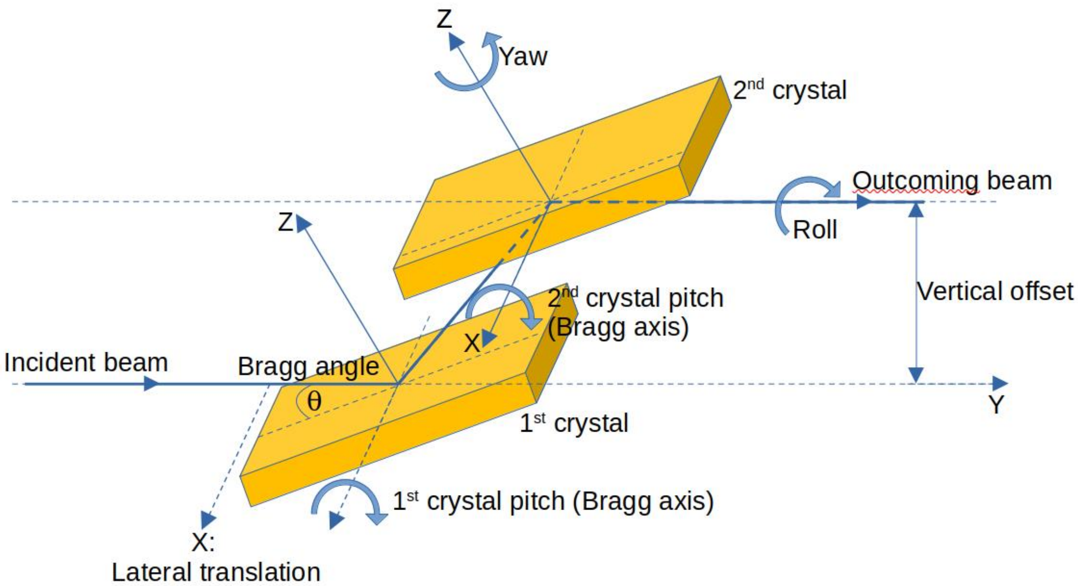


Figure 8. *Nomenclature of the DCM/DMM motions for SMAUG monochromator.*

Practical items:

9.2.3. Equipment masses

The mass of equipment, used in construction of SMAUG beamline, should allow them to be movable either by Solaris crane (of 8 tons capacity, 4 m of the maximum height of crane hook above ground), or to employ the solutions allowing rolling them on the floor into the hutch.

9.2.4. Lifting arrangements

The following components must be equipped with transportation loops or lifting points to fit the vessels with the crane to its final position in the hutch: granite plinth (lifting of the complete assembly), vacuum vessel, goniometer, crystal cage.

9.2.5. Alignment

The alignment of the system is all related to the Bragg axis defined by the centre of the goniometer shaft. This should be the principle alignment fiducial. Additional fiducial mounts should be provided upon request at no additional cost.

9.2.6. Primary stage and support system

The primary stage should comprise the following major items:

- One off worm wheel drive goniometer or other appropriate goniometer with encoder system;
- One motorized slide system for positioning the goniometer in the lateral direction across the beam during initial set up and for the crystal set selection;
- Granite support plinth.

An alternative solution with justification can be presented by the Contractor.

The primary stage should consist of a high precision goniometer with a horizontal axis of rotation. This (component) will be aligned to be perpendicular to the beam axis reflected from the VCM upstream. A substantial granite plinth should support the goniometer and crystal cage for maximum stability.

A mechanism allowing to adjust the whole monochromator's assembly height, pitch and roll should be provided to allow alignment to the incoming beam axis. Documentation of the measurements of the primary stage performance/stability should be provided upon delivery.

Specific parameters of the primary stage motions should be specified and presented with justification by the Contractor (example set of the primary stage performance requirements is presented in Table 4).

9.2.7. Control of Bragg Angle

The Bragg angle control should be achieved with a fully closed loop system. The goniometer should be actuated by a worm wheel mechanism or other appropriate goniometer with encoder system which, in turn, should be driven by a geared two-phase stepper motor. The rotary table should be fitted with two limit switches to prevent the overtravel of the crystal cage.

9.2.8. Lateral translation

The lateral stepper-motor driven translation of the assembly should enable selection between crystals and multilayers sets.

9.2.9. Crystal Cage

The crystal cage should comprise the following major items:

- Silicon Crystals (X1, X2);
- Multilayer Mirrors (ML1, ML2 and M3, M4);
- Water cooling system complete with connections to the cooling feedthrough;
- Optic cooling assembly, including thermocouples for temperature monitoring;
- 1st optic mounting assembly;
- 2nd optic mounting assembly,
- Crystal cage structure,
- Electrical feedthroughs for the signals associated with the *in-vacuum* motors and actuators listed above.

The system could be equipped in thermocouples only if the Contractor will expect need for temperature monitoring

Depending on the proposed solution, diffractive optics mounting assemblies should be separate for silicon crystals and multilayers. Mounting assemblies should be equipped with necessary adjustments stages (stepper motor driven and fine piezo stages for rapid scanning and beam position corrections) that enable optics alignment for the proper operation.

Specific parameters of the crystal cage motions should be specified and presented with justification by the Contractor (example of the crystal cage performance requirements is presented in Table 4).

Table 4. Crystal cage performance requirements – an example.

Motion description	Parameter	Value(s)

1st Optic Roll	Range	≥ ± 0.5°
	Resolution	≤ 0.5 µrad
	Repeatability	≤ 2.5 µrad
2nd Optic Vertical	Range	TBA*
	Resolution	≤ 0.25 µm
	Repeatability	≤1 µm
2nd Crystal Pitch	Range	≥ ± 0.5°
	Resolution	≤ 0.5 µrad
	Repeatability	≤ 2.5 µrad
Fine 2nd Crystal Pitch	Range	≥ 125 µrad
	Resolution	≤ 0.02 µrad
	Repeatability	≤ 0.05 µrad
2nd Multilayer Pitch	Range	≥ ±0.5°
	Resolution	≤ 0.5 µrad
	Repeatability	≤ 2.5 µrad

*should be proposed on PDR

9.2.10. Crystals

A Si(111) crystal set should be supplied with the monochromator. The crystals should be delivered with the standard quality documentation including measurement of the slope error, roughness and X-ray verification of rocking curves (angular dependencies of the Bragg reflectivity).

Crystal lateral dimensions should enable acceptance of the full X-ray beam coming from the VCM and full transmission of it further downstream. Crystal depth should be chosen accordingly, including thermal and mechanical considerations into account.

The general standards to crystals have to comply are:

- 1 mm × 1 mm chamfer around the optical surface;
- 0.25 mm × 0.25 mm chamfers elsewhere;
- Manufactured from float zone dislocation-free silicon;
- Orientation/miss-cut accuracy ± 0.05°

- Tangential Slope error ≤2 µrad RMS, *(deviations from the RMS value assumed here may be accepted after the Contractor presents a justification, however not later than during PDR*;
- Diffracting surface flatness <5 µm RMS over the whole optical surface;
- Super polished to roughness **≤0.5** nm RMS, *(deviations from the RMS value assumed here may be accepted after the Contractor presents a justification, however not later than during PDR*;
- Etched to remove the surface strain;
- No visible scratches, etched pits of texture on the optical surface;

All results of metrology tests (shape errors - surface roughness, slope errors, measured by Nanometer Optical Measuring (NOM) or equivalent system and by Long Trace Profiler (LTP) or equivalent; miscut of the crystals and rocking curve profiles, measured by X-ray diffractometry) of the crystals should be provided.

Any deviations from above mentioned specifications are acceptable only if justified and proven that it will not worsen the DCM's performance.

9.2.11. Multilayers

The multilayer set(s) for the DMM should be delivered with quality documentation including characterization of performance with X-rays, also with the metrology data characterizing the substrates before deposition of the multilayers. Required parameters for substrates and multilayers are listed in Tables 5 and 6.

The optimal solution (preferred by Ordering Party) is to implement two sets of multilayer stripes in DCM/DMM, one ML set (ML1, ML2) should be optimized for narrow bandwidth and high peak reflectivity and one (ML3, ML4) for wide bandpass.

Table 5. Multilayer substrate requirements.

Parameter	Specification
Substrate Material	Silicon (001)
Tangential Slope Error	≤ 0.5 µrad RMS*
Sagittal Slope Error	≤ 2.5 µrad RMS
Surface Roughness (Mid)	≤ 0.25 nm RMS with 1 – 170 µm sampling

Surface Roughness (High)	≤ 0.15 nm RMS with < 1 μm sampling

** deviations from the RMS value assumed here may be accepted after the Contractor presents a justification, but not later than during PDR.*

Table 6. Multilayer requirements.

Parameter	Specification
Multilayer (ML) pairs	2 (ML1, ML2), (ML3, ML4)
Energy range	eg. 6-8, 8-14 keV*
Width of active area	≥ 10mm
Reflectance of ML2 and ML4 at 12 keV (R_{12})	≥ 84% (i.e. ≥ 70% for ML pair)
Vertical beam acceptance of ML2 and ML4 at 12 keV	≥ 3.5 mm
Bandwidth – FWHM	0.8 – 2 %**

** detailed energy range should be proposed by Contractor not later than on PDR*

*** detailed bandwidth should be proposed by Contractor not later than on PDR*

The choice of the materials for specific energy range, periods of the layers, etc. is left to the Contractor, and should be specified in the offer. The width of the active optical area of both multilayers should be greater or equal to 10 mm (TBA*). The reflectance should be guaranteed to within 10% of theoretical values. The exact number of layers in the multilayer structure should be determined experimentally and agreed with the customer prior to final deposition.

**width of the multilayer structure should accommodate the full horizontal width of the incoming X-ray beam.*

9.2.12. Crystal Assembly, radiation collimator and cooling

The optical components – crystal and multilayer – should be cooled with water. The power of the beam reflected from the VCM is on the order of about 3 W (TBD). The cooling arrangement of the monochromator optics should be designed to accommodate an absorbed power, whose value should be precisely determined with dedicated Finite Element Method calculation. At the same time, the cooling system should not introduce vibrations into the optics.

Thermocouples should be fitted to the optics and electrical feedthrough will be provided and the temperatures made available for monitoring and collection of signal from them.

The radiation collimator should be installed near exit port area the DCM/DMM vessel, downstream of the monochromator. It has to have a maximum opening of 2 $cm_H \times 1\ cm_V$, with minimum transverse dimensions with respect to the white-beam axis of -5 cmH to +5 cm_H and -5 cm_V to +6 cm_V, composed of a 2 cm thick Cu plate, followed by a 3 cm thick W plate. Here the index H denotes horizontal direction, and the index V denotes vertical direction.

9.2.13. Crystal Cage Materials

The crystal cage should be constructed from materials compatible with a VHV environment. The actuators used in the crystal cage should be designed for vacuum operation. All materials, finishes and preparation processes used in their manufacture should be compatible with vacuum environments. NSRC SOLARIS standards regarding vacuum materials and procedures are described in Appendices VAC1 and VAC2.

9.2.14. Vacuum System

The system comprises the following major items:

- One Vacuum vessel
  One door for the vacuum vessel.

The vacuum components should be generally designed in accordance with VHV practice. This means that the vessel should be constructed from stainless steel and cleaned and prepared in line with this requirement. The system, after vacuum bakeout (if necessary), should be designed to operate at a pressure of less than 1×10^{-7} mbar.

The vessel should contain the primary stage and the crystal cage. The design of the form of the vessel is left to the Contractor, to best accommodate the functionalities of the DCM/DMM.

Vacuum requirements for DCM/DMM shall be compatible with UHV or at least VHV standard:

- Base pressure ≤ $5 \cdot 10^{-8}$ mbar
- Leak rate level (sum of all leaks) ≤ $1 \cdot 10^{-9}$ mbar·l/s
- RGA criteria: the sum of the partial pressures of masses above mass 44 up to 100, is less than 5 x 10^{-3} of the total pressure in a leak-free system with a total pressure below $1 \cdot 10^{-7}$ mbar
- Outgassing rate ≤ $1 \cdot 10^{-11}$ mbar·l·sec^{-1}·cm^{-2} (if this procedure can be applied for the particular technical solution proposed by Contractor).

All viewports should be made of fused silica glass as standard. All ports for the electrical signal feedthroughs associated with the actuators and motors in the crystal cage should be mounted in the way, that allows disconnection of the vessel body without the need to disconnect cables first.

The vessel should be designed in the way allowing the easy access to the primary stage and the crystal cage after opening.

Manual alignment/adjustment should be provided in addition to the overall adjustments provided by the primary stage jacks (see Appendix ALIGN).

All the Commercial-Off-The-Shelf (COTS) vacuum components (e.g. ion pump, vacuum gauges, valves, safety valves, etc.) should be in agreement with NSRC SOLARIS guidelines described in Appendix VAC1.

9.2.15. **Support plinth/girder**

In the support structure of the DCM/DMM monochromator a massive block of granite should be used as a seismic mass for the system. It should be bolted to the facility's floor via a grouted steel baseplate. Manual adjustment should be also planned (for use at the installation stage) to allow x, y, z and angular adjustment of the DCM/DMM system via jacking bolts on the grouted baseplate (see Appendix ALIGN for required ranges and precision).

9.2.16. **Motors and Encoders**

All motions will be driven by two-phase stepper motors. The use of *in-vacuum* motors should be agreed with NSRC SOLARIS before the Final Design Review (see Appendix CS0). Ordering Party allows the use of piezo actuators for particular technical solutions (eg. fine pitch of second optics).

All motions should be fitted with encoders (see Appendix CS1 regarding standards and practices used at NSRC SOLARIS for the motorization). Other solution should be reported by

Contractor and accepted by Ordering Party and SOLARIS team. The Ordering Party allows the use of piezoelectric actuators in special technical solutions (e.g. small movement of the second optic).

9.2.17. Controls Interface Panel

Cables from the monochromator should run from patch panel to the control panel or rack on the side of the Local Controls Cabinet from which the field cables connect and cables should be available. The field cables and hardware controls are not included in the scope of supply.

9.2.18. Digital Piezo Transducer

The fine piezo motion of the 2nd crystal should be driven with vacuum-compatible stack actuator. It may be provided fitted with a closed loop sensor (strain gauge). The piezo stack actuator should be fitted with Kapton-coated *in-vacuum* wiring which should be covered with stainless steel braiding to minimize the impact of scattered radiation. The piezo stack motion controller and driver are included in the scope of supply.

9.3. Vertically Focusing Mirror (VFM)

The main roles of the VFM are:

- to collect the photon beam reflected from the DCM/DMM;
- to focus it on the vertical direction between the SAXS sample position and the end of the SAXS tube (variable bending)
- to reestablish horizontal direction of beam propagation.

It should be oriented horizontally – reflecting the photon beam upwards (see Figure 9).

9.3.1. Definition and references

The diagram shown in Figure 9 indicates the relationship of the various degrees of freedom referred to throughout this specification. These are shown with respect to the beam path.

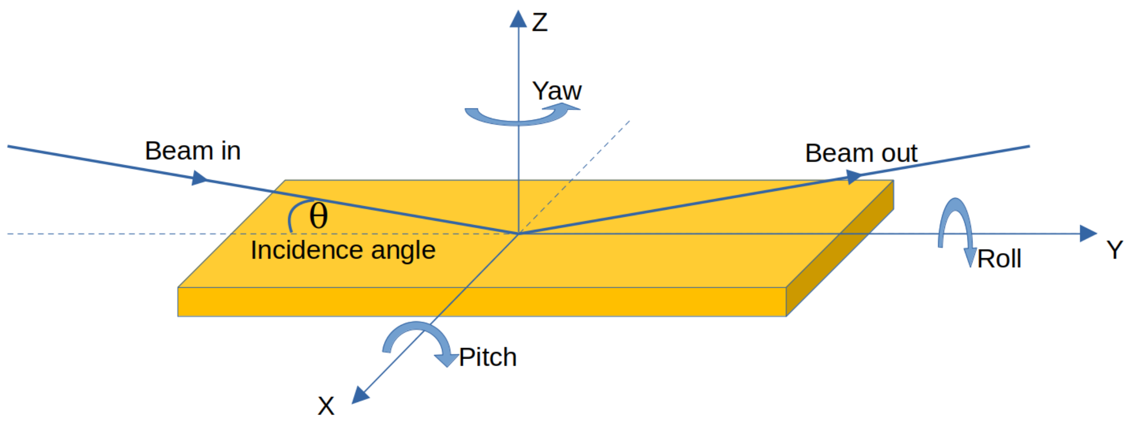


Figure 9. Nomenclature of the VFM motions.

Mirror parameters are listed in Table 7.

Table 7. Required parameters of the VFM

Parameter	**Specification**
Operating position	Vertically Focusing Mirror
Nominal working incidence angle	5 mrad
Max. Incidence angle	5.2 mrad
Stripes	Rh
Active area of single stripe	~ 850 × 20 mm
Blank dimension	~ 900 mm
Shape	Bendable tangential cylinder *however Contractor can propose other shape (eg. Cylinder or toroidal cylinder) with justification*
Radii of curvature	Depends on the location, TBA*
Slope error	< 1 µrad RMS
Cooling	Slot-cooling or passive cooling or other effective method proposed by the Contractor

**Radius of curvature of the VFM should be calculated according to the formula: $R = 2q/\sin\theta$, where R – radius of curvature, q – distance of VFM to the focal point, θ - grazing angle of the mirror. E.g. q = 30 m (middle of the SAXS tube) and θ = 5 mrad, it results in R = 12 km.*

All details regarding the optics shape, dimensions and surface quality have to be presented in the Offer with the justification of proposed values.

All metrological tests data regarding the optics surface quality and shape errors (surface roughness, slope errors, etc.) have to be provided during Factory Acceptance Tests.

9.3.2. Cooling

The mirror will be water cooled, only if it is necessary. Direct water-to-vacuum joints are not permitted. The beamline will be operated only with DCM/DMM. Therefore, the expected absorbed power here is in a range of about 0.2 Watt, and water-cooling will not be needed at all. However, this concept depends on the technical properties of the component proposed by Contractor. Details of the cooling system are left to the Contractor to design, and the proposed (or exemplary) cooling scheme (or reference) should be presented in the offer. NSRC SOLARIS standards of cooling water and water system are described in Appendix WAT-CW1 and should be followed during the design phase.

9.3.3. Diagnostic fluorescent screen

For the diagnostics of the incoming photon beam, a screen should be fitted to the front of the optic. The screen should be coated with a phosphor coating that will be illuminated by the incident beam. Therefore, a viewport in the vacuum vessel should be planned in line with the mask and should be used by the customer to fit their own CCD camera (cameras from the series Basler Ace, e.g. acA1280-60gm or compatible are the standard devices used in NSRC SOLARIS).

9.3.4. Mirror mechanism

The motorization mechanism of the mirror assembly should ensure to control pitch, roll, yaw and lateral translations (horizontal and vertical). All movements should be driven by a two-phase bipolar stepper motor. The jacks should be protected from overtravel by limit switches. Positional feedback should be provided by encoders (see Appendix CS1 regarding NSRC SOLARIS requirements for the motorization).

VFM motions should be specified and presented by the Contractor. Example set of the requirements for the mirror are presented in Table 7.

9.3.5. Support plinth/girder

For the support of the VFM structure, a massive block of granite should be installed as a seismic mass for the mirror system. It should be bolted to the facility's floor via a grouted steel baseplate and support the mechanical adjustment stages of the optics.

Manual adjustment should be also planned (for use at the installation stage) to allow x, y, z and angular adjustment of the mirror assembly via jacking bolts (or push blocks) on the grouted baseplate (see Appendix ALIGN for required ranges and precision).

9.3.6. Vacuum vessel

All mechanisms inside the UHV space shall use UHV compatible materials with dull polished or machined finish, which shall be cleaned according to the NSRC SOLARIS vacuum standards. The NSRC SOLARIS vacuum standards are described in Appendices VAC1 & VAC2. UHV compatible joining methods (welding, vacuum brazing etc.) shall be used throughout. Lifting points shall be planned on the vessel lid.

Vacuum requirements for VFM must be compatible with UHV or at least VHV standard:

- Base pressure $\leq 5 \cdot 10^{-10}$ mbar
- Leak rate level (sum of all leaks) $\leq 5 \cdot 10^{-10}$ mbar·l/s
- RGA criteria: the sum of the partial pressures of masses above mass 44 up to 100, is less than 5 x 10^{-3} of the total pressure in a leak-free system with a total pressure below $1 \cdot 10^{-9}$ mbar
- Outgassing rate $\leq 1 \cdot 10^{-11}$ mbar·l·sec^{-1}·cm^{-2} (only if this procedure can be applied for the particular technical solution proposed by Contractor)

The vessel baseplate shall be fitted with points for mounting fiducials for alignment during installation in accordance with NSRC SOLARIS requirements (described in Appendix ALIGN).

A list of planned vacuum ports must be presented in the offer together with specification and justification of the purpose (e.g. beam inlet, beam outlet, ion pump, RA valve for roughing pump, viewports, gauges, cooling and electrical feedthroughs, mirror support, loading and

maintenance etc.). The exact number, specification, justification and positioning of these ports must be discussed during the design phase and approved before manufacture commences.
General requirements of the vacuum standards at NSRC Solaris are presented in Appendix VAC1 & VAC2.

9.3.7. Motors and Encoders

All motions will be driven by two-phase stepper motors. Use of *in-vacuum* motors should be agreed with NSRC SOLARIS before the Final Design (see Appendix CS0).

All motions should be fitted with encoders (see Appendix CS1 regarding standards and practices used at NSRC SOLARIS for the motorization).

9.3.8. Controls Interface Panel

Cables from the VFM should run to the control panel or rack on the side of the Local Controls Cabinet from which the field cables connect and cables should be available.

9.4. Beam defining slits

Slits (horizontal and vertical) should be moved with the stepper motors. Resolution and repeatability should be on the order of the 1 μm and fitted with encoders. Full opening of the slits should allow to pass full monochromatic beam. In fully close state, the overlap of the blades should ensure total blockage of the beam.

9.5. Beam shutter with fluorescent coating

Downstream VFM vessel the beam shutter element with fluorescent coating should be installed. The thickness of the beam shutter has to be at least 2 mm (if made of copper or stainless steel). The shutter shall be pneumatically driven and have two positions: open position and closed position. Each position shall have two redundant sensors to indicate open and closed position (in total 4 sensors). The “in beam” shutter position should have an accuracy and reproducibility of 0.1 mm or better. The shutter shall obstruct the bremsstrahlung in the bottom position to ensure closure by gravity in case of pneumatic or electrical failure. The vacuum vessel should be equipped with a view port suitable to observe the shutter front with a CCD camera.

9.6. Beam transfer tube with pumping stations (between optical hutch and experimental hutch)

Between the X-ray optic hutch and end station hutch the synchrotron radiation transfer line with appropriate pumping stations should be installed. The radiation shielding properties required a steel thickness more than 0.5 mm (preferred 2 mm). In other words, the structural minimum steel thickness for the vacuum pipe between the optics hutch and the experiments station will satisfy the minimum shielding requirements, and therefore no extra shielding will need to be foreseen.

9.7. Components after beam transfer tube, located in the experimental hutch

The experimental hutch will house the final components of the optical section for the final beam-shaping stage and for beam monitoring (beam conditioning unit), which must include at least: **a pumping cross module, a beam monitor (BPM or nanoBPM), anti-scatter slits, beam tube, shutter, guard slits, filter array**. The mentioned above components in the Experimental Hutch **can be mounted onto a motorized 5-axis motion table**. This table should be located before XEUSS 3.0 UHR system.

The role of the anti-scatter slits is to reduce the residual parasitic scattering, form the expected shape of the beam cross-section (they are used for effective suppression of the parasitic signal near the direct beam). The selection of the material for the slit leaves should take into account the specifics of SAXS/bioSAXS research, the use of scatter-less slits is expected. The Ordering Party allows the Contractor to propose an appropriate material. The Ordering Party also expects the Contractor to present also an appropriate and selected shutter and guard slits for this section in the offer. Detailed technical parameters should be established no later than during the PDR meeting.

The slits (horizontal and vertical) should be moved using stepper motors. Resolution and repeatability should be of the order of 1 μm and should be equipped with encoders. Full opening of the slits should allow the passage of a full monochromatic beam. In the fully closed state, the overlap of the blades should ensure complete blocking of the beam.

For the purposes of studied systems (eg. biological macromolecules in solution) susceptible to radiation damage, the Ordering Party provides for the possibility of installing a system of 2-4 filters that weaken the synchrotron radiation beam. The filter/beam weakener systems should be started using stepper motors. The exact number and arrangement of filter foils should be determined in the FDR.

The components of the optical section located in the experimental hutch should have stable support that ensure alignment in horizontal and vertical directions, and in angular degrees of freedom. The chamber should fulfil general UHV/VHF requirements. The last component of the optical section (terminated window) should be prepared for connection with endstation (XEUSS 3.0 UHR, Xenocs, Grenoble, France).

9.8. Beryllium/SiN windows

Terminating water cooled Be window will be located after FE section at the entrance to the BioSAXS optical section. **The FE section (and 1st Be window) is a subject of separate tender.** The technical details for FE terminating window will be available (if necessary) at X-ray optics design phase, after the completing the tender for Front End section (September 2024).

Second (terminating) window (SiN or Be) is included in this tender procedure (Section 9.8.1).

In case of choosing a Be window, it is necessary to present the installation procedure considering issues related to the risk of window damage.

9.8.1. Terminating Window

The optical section should be enclosed by window (2nd window) prepared using Silicon Nitride (SiN) or Beryllium, to terminate the vacuum space of the optical section. The solution preferred by Ordering Part and SOLARIS is the window constructed using SiN. However, for the beryllium window it is required to use IF-1® brand beryllium with a purity of 99.8% or better. Modifications in the required parameters for the window can be proposed by the Contractor, however only while keeping safety factor as high as possible.

Set of basic requirements for the window:

- mounted into the standard CF flange,
- coated from the air side,
- the beryllium window should withstand a pressure difference of at least 1.5 bar in both directions,
- ultra-high vacuum tight (proper vacuum level and He leak rate),
- safety factor of the window > 4.

10. Vertical beam position in and after the optical section

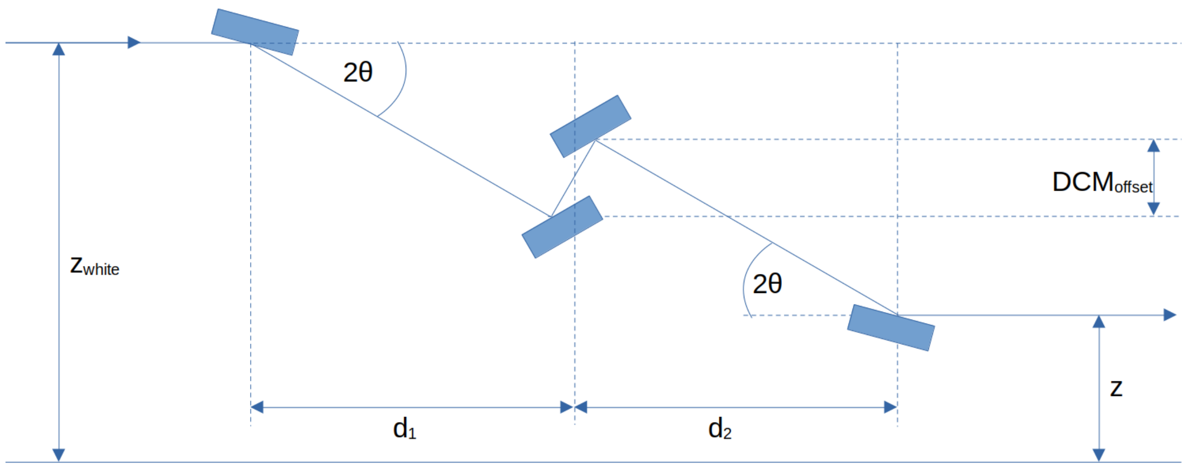


Figure 10. *Simplified drawing of a beam geometry going through the optical setup.*

After the beam transfer through complete arrangement of the optical system, the height of the beam can be calculated according to the formula:

$Z = z_{white} – d_1*2\theta + DCM_{offset} – d_2*2\theta$

where:

z_{white} = 1300 mm

d_1=2000 mm

θ = 5 mrad (2θ = 10 mrad)

DCM_{offset} = 20 mm

d_2=2500

Then $z = 1300 – 2000*10*10^{-3} + 20 – 2500*10*10^{-3} = 1275$ mm

This is the optimal beam height (1275 mm from the floor level) for the SAXS endstation. This means that the combination of respective distances of the elements and vertical offset of the DCM/DMM should maintain this vertical position. Graphical representation of optical setup is presented in Figure 10.

11. Beam position monitoring system

Apart of the XBPM in the front end section, it is necessary to monitor and record the spatial information of the photon beam in the initial alignment process of the beamline, as well as in later stages. This should be done with X-ray Beam Position Monitor devices.

It is expected that the Contractor will propose the scheme of the Beam Position Monitoring system (including type, position and number of the devices) for the beamline to achieve adequate precision of the monitoring.

The real-time, fast feedback system that allows simultaneous stabilization of both beam position and energy at the highest possible frequency should be included and this system is a criteria of offer evaluation.

Type of the BPM at a certain position should be compatible with the power of the photon beam at a certain location (adjusted to the power transmitted by a certain optical element).

Suggestion of the precise type, arrangement and number of the BPM devices together with control and readout electronics is left to the Contractor.

The Contractor should state the precision of the given BPM in the Offer. Sub-micron precision is expected, although the arrangement of the devices should be done in a way optimizing the cost/precision ratio.

All devices should be in agreement with SOLARIS standards (i.e. compatible with Tango system). Device servers for the non-standard devices should be provided.

The XBPMs should be supplied with a motorized positioning system including absolute encoders and limit/over travel switches. All electronics shall be shielded from the radiation.

The exemplary specification of the main components of the SMAUG optical section presented in Chapter 8 (*Scope of the order, general list of components and preliminary layout*) includes the proposed components of synchrotron radiation beam diagnostics systems. **The Contractor may present an alternative concept for the Beam Position Monitoring system.**

12. Vacuum systems

The proposed division scheme into vacuum sections is presented in Figure 5. Due to the specific technical requirements of individual optical components (mirrors, monochromator), the size of the entire optical section and the intended use of the beamline for measurements using X-ray radiation in the energy range of 6-15 keV, the Ordering Party leaves the final proposal to the Bidder the division of vacuum sections.

All pumping systems necessary for maintaining of the proper vacuum in the X-ray optics and beam transfer line should be included in the offer.

The DCM/DMM can be considered as operating in UHV or VHV regime, with a base vacuum of $\leq 5 \times 10^{-8}$ mbar. This value should be measured when all sputter ion pumps, vacuum gauges and chillers are operating and all vacuum valves are closed. The integral leak rate (sum of all leaks) should be $\leq 2 \times 10^{-9}$ mbar·l/s He. The system should be considered free of hydrocarbons if in a leak-free system with a total pressure below 1×10^{-7} mbar the sum of the partial pressures of masses above mass 44 up to 100, and excluding AMU 69, is less than 0.5% of the total pressure.

Other vessels proposed for the optical section should be characterised by a base vacuum of $\leq 5 \text{ x } 10^{-10}$ mbar measured when all sputter ion pumps and vacuum gauges are operating and all vacuum valves are closed. The integral leak rate (sum of all leaks) has to be $\leq 5 \times 10^{-10}$ mbar·l/s He. Tested system is considered free of hydrocarbons if in a leak-free system with a total pressure below 1×10^{-9} mbar the sum of the partial pressures of masses above mass 44 up to 100 is less than 0.5% of the total pressure.

The Beam Conditioning Table (beam conditioning unit) at the end of the beamline should be in at least in HV regime with a base vacuum of $\leq 1 \text{ x } 10^{-6}$ mbar measured when all pumps and vacuum gauges are operating and all vacuum valves are closed. The integral leak rate (sum of all leaks) has to be $\leq 1 \text{ x } 10^{-7}$ mbar.l/s He.

However, the Ordering Party also leaves the Bidder with a proposal for specification of UHV, VHV or HV requirements for individual vacuum sections. The scheme of vacuum sections division together with its justification should be presented no later than during the PDR. The final version must be agreed with the Ordering Party representatives and the NCPS SOLARIS team during the FDR.

13. Miscellaneous items

The Ordering Party requires that when designing the line optics, the Contractor takes into account the specificity of the beamline and optimises the arrangement of individual optical elements in such a way as to reduce the background and achieve beam stability in the optical section.

The primary slit (white beam slits) can be proposed in the design if they will be useful to reduce the heat load on the monochromator and further collimate the beam. The slit between the monochromator and toroidal mirror would can be considered to control the illumination on the mirror.

The location of beam defining slits, anti-scatter slits and the guard slits should be effective for blocking the scattering from the slit before.

The Ordering Party leaves it up to the Contractor to select and locate the thermocouples for effective temperature control on those optical elements that require it. This information should be presented in the offer and specified at the PDR stage.

14. BioSAXS/SAXS end station

The end station of the SMAUG beamline will consist a SAXS camera, which should be suitable for bio-SAXS measurements (about 60 % of planned experiments) as well as high-resolution SAXS measurements. This SAXS camera (XEUSS 3.0 from XENOCS, Grenoble, France) was already purchased in the separate order. The expected installation time of the end station is December 2024.

The end station will be used in two experimental modes determined by the choice of radiation source.

The first mode includes operation using two stationary (laboratory) sources intended for research before the final integration of the end station with the SOLARIS synchrotron and also in periods when, for technical reasons (service downtime), the synchrotron ring is turned off. Therefore the end station system (SAXS camera) must have a stationary source consisting of at least two independent X-ray tubes integrated with an appropriate generator or generators and an optical system that will allow the system to operate in a situation when synchrotron radiation is not supplied.

The second experimental mode involves the use of synchrotron radiation supplied to the SAXS system from the BM02 SOLARIS bending magnet via the optics of the SMAUG beamline.

The exemplary scheme of the SAXS system (XEUSS 3.0 UHR) connected to two X-ray tubes and with open port for synchrotron radiation is presented in Figure 11.

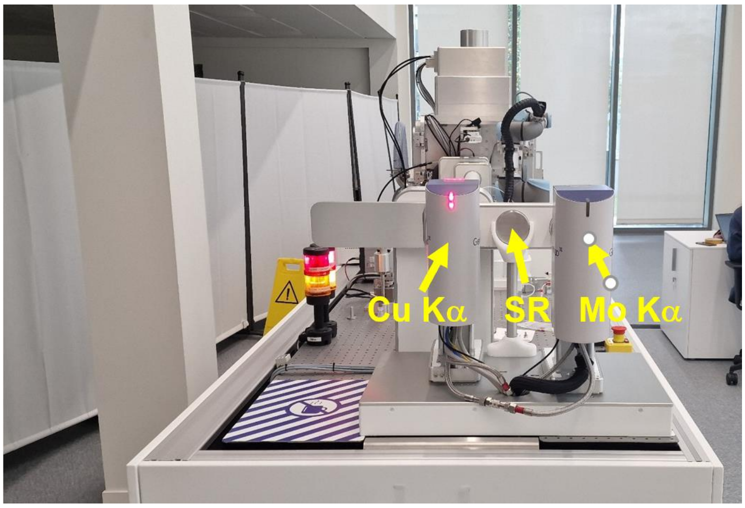
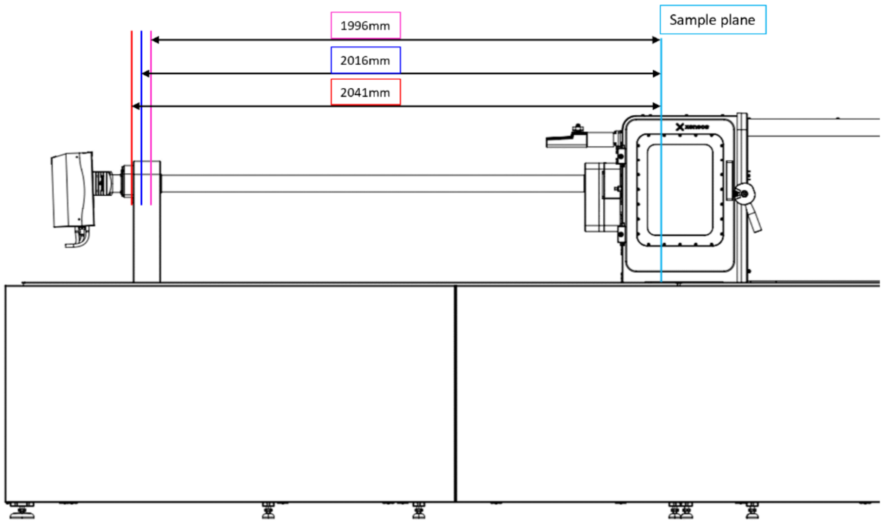
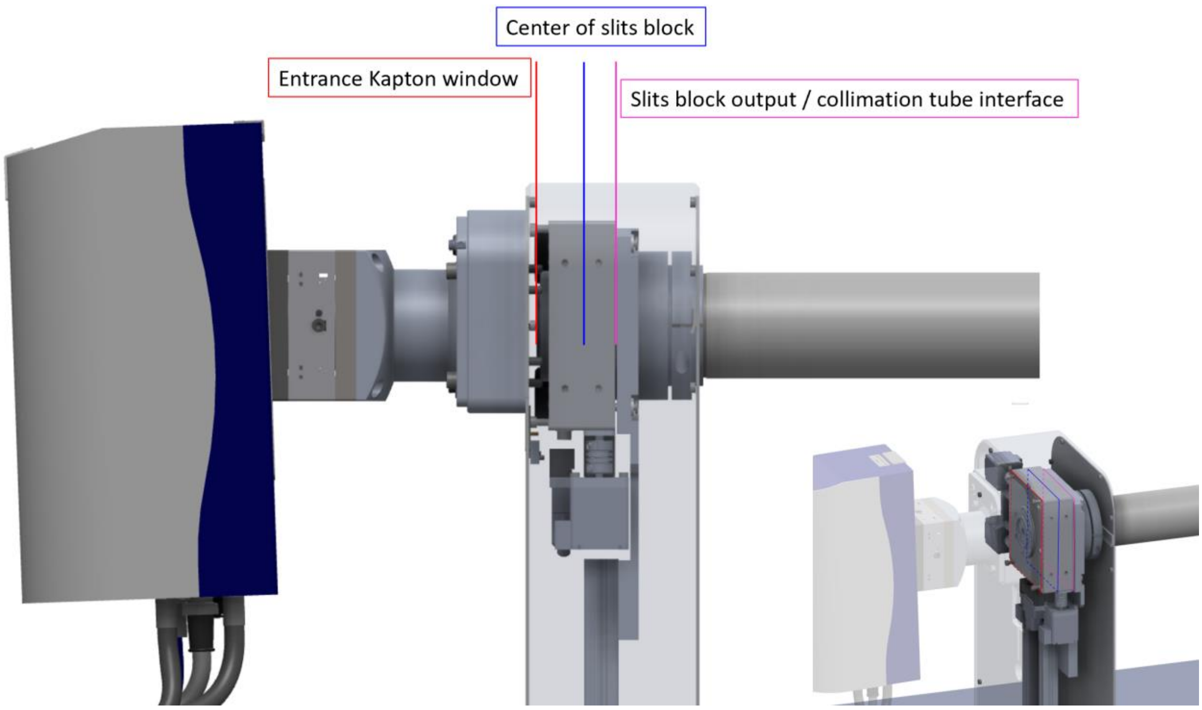


Figure 11. *The exemplary view of the SAXS system connected to two X-ray tubes (Cu Kα, Mo Kα) and with open port for synchrotron radiation.*

The Ordering Party expects that the Contractor, during the design work and construction of the optical part of the SMAUG beamline, will take into account the optimal solution that will allow for connecting the end station in the configuration described above. The contractor will provide all required technical data of the designed X-ray optics of the SMAUG beamline, in particular the height of the beam from the hall floor at the integration point and the parameters of the photon stream (diameter, intensity).

The general drawings of the XEUSS 3.0 system from the source site with dimensions are presented in Figure 12.


1996mm
2016mm
2041mm
Sample plane


Center of slits block
Entrance Kapton window
Slits block output / collimation tube interface

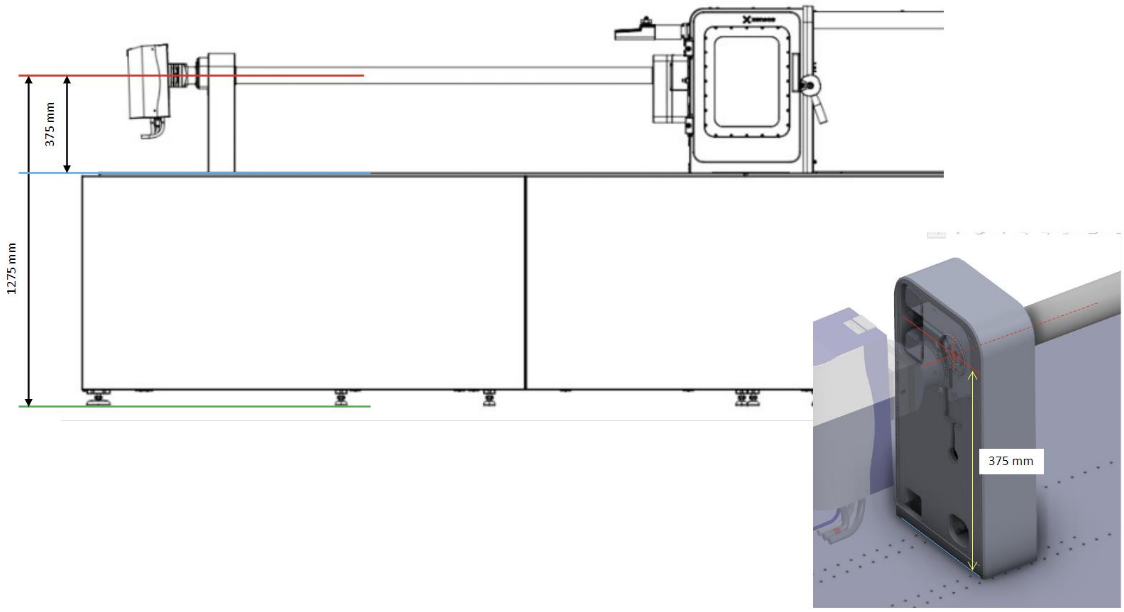


Figure 12. *The drawings (with permission of XENOCS) presenting XEUSS 3.0 UHR system from X-ray source site.*

15. Other requirements

The Contracting Authority expects that the SMAUG beamline X-ray optics, made under this tender, will be complete and ready for integration with front end and end station components to make fully operational beamline. In particular, this means that the beamline components specification provided by the Contractor will be complete. The Contracting Authority will not be forced to make additional purchases of components on his own, unless such a solution is previously discussed and agreed (such as IcePAP motor control system). The Purchaser also expects that the solutions proposed by the Contractor will offer the convenient control the optics of the beamline, monitor the beam position and correct its parameters.

16. Beamline design – contract stage

The Ordering Party expects the Contractor to submit a preliminary design report (PDR) and next a final design report (FDR). In the first stage of the contract, the Contractor will submit a preliminary design, which will be analysed and assessed by the Purchaser's teams (Ordering Party and SOLARIS teams as well as members of the advisory committee).

Approval of PDR by the Contracting Authority and also the list of all comments to the design will be communicated to the Contractor within 4 weeks. The Ordering Party reserves the right to consult the project also with external advisors. These comments should be included in the final design (FDR). Works on the final design (FDR) may be continued subject to the approval of the introduced changes by the Ordering party and SOLARIS team. The approval of the introduced changes into the design should be granted by Ordering Party within 2 weeks after providing the necessary documents.

16.1. Preliminary design report (PDR)

The preliminary design report is required to include:

- Description of the proposed beamline concept.
- The scheme of the complete beamline geometry.
- Proposed arrangement of the individual beamline components in the area reserved for SMAUG in the new experimental hall sector.
- A detailed technical description of the proposed beamline components.
- Detailed technical description of all optical elements (type, size, radius of curvature, substrates used in multilayer optics, etc.).
- Technical description of the complete beamline.
- Results of theoretical validation of the assumed beamline geometry in the form of the results of calculations of beam track and beam parameters using the ray tracing method for the full beamline geometry. The BM02 parameters are provided by NSRC SOLARIS.
- Preliminary scheme of the cooling system for all beamline components requiring the water cooling.

- The results of calculations by the use of the finite element method for all components exposed to the synchrotron radiation (allowing to estimate the maximum temperature and the cooling efficiency estimated for the proposed solutions).
- Proposed preliminary scheme of the compressed air system.
- Proposed technical guidelines for the beamline hutch, especially including the functional aspects (design constraints related to the location of all components and their installation process, limitations for the beamline infrastructure, etc.).
- List of all crucial vacuum components and their technical parameters (valves, vacuum gauges, vacuum pumps, etc.).
- Description of motorized axes (types of motors, number and types of encoders).

16.2. Final design report

The final design report is required to include:

- Detailed description of the final beamline concept.
- Detailed technical description of the SMAUG beamline components.
- Results of theoretical verification of the final beamline geometry - results of calculations of the beam path and beam parameters by the use of the ray tracing procedure for the full and final beamline geometry.
- Detailed design (and schemes) of electrical and power systems.
- Final detailed design (and schemes) of cooling system for all components using water cooling.
- Detailed final scheme of compressed air system.
- Final design (full schemes) of beamline presented as 3D and 2D drawings, taking into account the location of all beamline components.
- The layout of all required connections for SMAUG beamline components (cooling water, compressed air, power systems, control panels, racks, cable connections, etc.).
- Final list of all motorized axes (number and type of motors needed, number and type of encoders needed).
- Detailed guidelines for the beamline hutch from the functional side (internal location of components and infrastructure etc.).
- All necessary information required for the design of the beamline safety systems.

- Design of the scope of installation works with the division of tasks for the Contractor and the Contracting Authority.
- A detailed procedure to be followed in the event of a beryllium window failure in a vacuum system.

16.3. Factory/Site Acceptance Tests (FAT/SAT)

Full specifications and procedures covering all factory testing should be prepared in advance and these will be submitted to the Contracting Authority prior to final design approval.

Representatives of Ordering Party (UAM) and NCSR SOLARIS will have the possibility to witness the tests and must be informed about the date of the test 8 weeks in advance. FAT (or SAT) should include the training of employees of Ordering Party and SOLARIS in handling the subject of the contract.

Testing should consist of Motion Testing, Vacuum Testing and Fiducialization. The factory tests include the following aspects of the performance:

- Optical elements tests to ensure that all specifications are met, including tests by the use of X-ray radiation of crystals and multilayers;
- Motion tests to ensure that all movements operate throughout their working ranges and measurement of the accuracy, resolution and repeatability of all motions, and effectiveness of limit switches;
- Pressure tests to ensure that the cooling circuits, including all couplings withstand 125 % of the operating pressures at their respective operating temperatures;
- Vacuum tests comprising leak testing of the vessels, total pressure measurement and residual gas analysis following bake-out;
- Helium leak checking to ensure that all sealing units are vacuum tight.

The systems shall be baked out (if it will be possible or required) and vacuum tested at the Contractor's facility prior to shipment. Vacuum testing shall include total pressure measurement and RGA scan of the vacuum vessels.

The nominal optics active surfaces should be referenced to the fiducial mount positions and the co-ordinates (X, Y and Z) provided to a precision of ±0.1 mm to establish the horizontal and longitudinal axes of the systems.

17. Documentation to be provided

All documentation must be in English or translated to English. Documentation has to be supplied in electronic form in generally accessible formats (dwg, dxf, step, doc, xls, pdf, etc.). Exemptions to be agreed.

17.1. Documentation to be provided with the Offer

a) Description of the proposed solutions with full technical details with (if possible/available) preliminary ray tracing calculations of the beamline optics performance.
b) Justification of the performances of proposed solutions (references, test reports on identical or similar equipment, calculations, etc.);
c) Confirmation of acceptance of all specifications.
d) Cooling concept and calculation of thermal load and cooling.
e) List of third party deliverables (vacuum components – bellows, vacuum pumps, gauges, valves) with detailed specifications of those parts.
f) Items to be provided by SOLARIS (electricity, water, compressed air, etc.).
g) Preliminary requirements on the cooling water e.g. flow, supply pressure etc. or other media to be supplied by SOLARIS.
h) A breakdown of costs.
i) Foreseen schedule.
j) List of the items that will be subcontracted and the names of the main subcontractors.
k) A list of previous similar or comparable projects.

17.2. Documentation to be provided/agreed upon the Final Design Review

A design review meeting will be held at Ordering Party site or SOLARIS site latest 15 weeks after start of the contract. The design report has to be presented 10 working days in advance. The design has to be approved by the Ordering Party and SOLARIS in written form within 10 working days after the meeting. The Ordering Party and SOLARIS approval will be limited to examination of the design with respect to the requirements stated in the technical specification of the Object of the order and the Contractor's offer. Any approval does not influence the Sellers responsibility for the overall performance and achieving the required operating characteristics. Documents to be provided:

a) Detailed technical specifications.
b) 3D CAD (step or iges) with 2D drawings (dwg or dxf)**:**
   Supplier should provide the full set of assembly drawings and all electrical drawings for operation and maintenance. However, Ordering Party and SOLARIS guarantees that detailed part drawings will not be released without written authorisation on a case by case basis.
c) Cooling diagrams.
d) Final list of monitoring and interlock signals.
e) Final list of recommended spare parts and cost.
f) Type of optical components, crystals, substrates for multilayers, multilayers type and properties with calculations of efficiency.
g) Final list of control parameters.
h) Clarification of interface problems (e.g. pressure, water, crane, pumps, cabling, etc.).
i) Items to be provided by SOLARIS (electricity, water, compressed air, etc.).
j) Description of the control system.
k) Test procedure for factory and site acceptance test.
l) Detailed description of standard maintenance work.
m) Information necessary for the correct / safe operation of the component.
n) Table of proposed motor and encoder models for each motorized axes, including range, repeatability, full step motion resolution and accuracy of each movement. All required data are described in the Appendix CS1.
o) Detailed schedule.

17.3. Documentation to be provided upon the Delivery

Documentation to be provided (exemption to be agreed):

a) Stock-taking document concerning all the delivered equipment included their serial numbers, dates of delivery, names of manufacturers named as per the sub-assembly drawing code as well as stock-taking document of all the delivered cables if needed.
b) Executive 3D CAD (step or iges) with 2D drawings. Supplier will provide the full set of assembly drawings and all electrical drawings for operation and maintenance.

However, SOLARIS guarantees that detailed part drawings will not be released without written authorization on a case by case basis.

c) Maintenance documentation and manuals.
d) Documentation of control and interlock soft- and hardware.
e) Documentation (manuals) of third party deliveries.
f) Results of metrology tests performed on the optical components**.**
g) Rocking curve measurements.
h) Factory acceptance test results.
i) Technical documentation, including 3D models, manuals, service manuals, technical drawings, description of installation and service procedures etc. Detailed list will be fixed during FDR meeting.

18. Project schedule (design, production, delivery)

The Contractor will present a detailed schedule of all activities described in this specification and deliver it within one month from the date of signing the contract (Table 8).

a) The schedule contains key dates of individual stages (designs, tests, deliveries) and is intended to provide a general overview of the design and production processes and to provide quick information on the progress of the project.
b) The schedule should include dates and delivery methods for all items to be delivered by the Ordering Party.
c) The schedule should include dates/periods for meetings, site visits etc.
d) The schedule should include deadlines for submitting documentation before individual stages.

Table 8. Summary of the main stages of the project.

Stage		**Elements necessary to consider the stage completed**	**Stage completion dates**
1.1	Start-up meeting/videoconference	Project schedule	Up to 3 weeks from signing the contract
1.2	PDR (Preliminary Design Review)	Contractor should identify all technical issues and proposed technical solutions.	Up to 2 months from signing the contract

1.3	FDR (Final Design Review)	Completion of detailed design. Acceptance of the FDR by the Ordering Party gives consent to production.	Up to 4 months from signing the contract
1.4	FAT (Factory Accep-tance Tests)	The agreed tests should be performed by the Contractor and approved by the Ordering Party.	Up to 17 months from signing the contract
1.5	Delivery of all beamline components	The items should be delivered to the indicated address and checked for any damage.	Up to 18 months from signing the contract
1.6	Installation of all beamline components	Installation of BL components should be performed by the Contractor under the supervision of the Ordering Party. The agreed tests should be performed by the Ordering Party under the supervision of the Contractor (if required) and the delivered equipment should successfully pass all tests. The Contractor will provide training to the staff on the appropriate maintenance and safe operation of the equipment being supplied.	Up to 21 months from signing the contract

19. List of attachments

The reference documents are appended with the following attachments. The Attachments include technological descriptions used in SOLARIS, which the Contractor shall observe and comply with. Attachments constitute an integral part of the Terms of Reference.

a. Appendix ALIGN1 – Guidelines in field of alignment
b. Appendix CS0 – SOLARIS Control System Standards
c. Appendix CS1 – Motion Control Standard
d. Appendix FE1-BM Guidelines for BM front end 02BM - general
e. Appendix MECH1 – Mechanics
f. Appendix MECH2 – Photon Beam orientation inside the VC2
g. Appendix MECH10-BM02 – Description of the BM02 beamline area
h. Appendix MECH11-BM02 – Dimensions of the BM02 beamline area
i. Appendix MECH13-BM02 – Dimensions of the BM02 beamline area (DWG)
j. Appendix MECH10-BM02 – Description of the BM02 beamline and front end area
k. Appendix MECH14-BM02 – Dimensions of the BM02 beamline and front end area
l. Appendix MECH15-BM02 – optical and experimental hutch
m. Appendix RAY-TRACING-BM02
n. Appendix SOURCE – synchrotron radiation source parameters
o. Appendix VAC1 – Guidelines for UHV Components at Solaris
p. Appendix VAC2 – Technologies and materials for SOLARIS UHV devices
q. Appendix VIB1 - Vibration characteristics of floor in experimental hall.pdf
r. Appendix WAT-CA1 – Compressed air basic standards
s. Appendix WAT-CW1 – Cooling water basic standards