Technical Specifications of Mirror Positioning System for Pre and Post Focusing Optics of Soft X-ray Beamline on Indus-2

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M.P. - 452013

Contents

1 Purpose

This document consists of technical specifications for the design and construction of two Mirror positioning system for the soft x-ray beamline on Indus-2 synchrotron source. Detailed description of source, the beamline and in vacuum Mirror positioning system is given below. A typical list of items to be supplied and the required technical specifications are specified in the document.

1.1 Indus-2 Source

Indus-2 is a 2.5GeV, 300mA, synchrotron radiation source with critical wavelength of about 2Å from its bending magnets. The bending magnet field is 1.502 Tesla. Source parameters for the proposed bending magnet port are σ_x=0.203 mm, σ_y =0.272 mm, σ_x'= 0.323 mrad, σ_y'=0.062 mrad. (X for horizontal and Y for vertical).

1.2 Description of Soft X-ray Beamline

A constant included angle varied line spacing plane grating monochromator (VLS-PGM) design is adopted for the soft x-ray reflectivity beamline on bending magnet port of Indus-2. The VLS-PGM consists of a spherical mirror and three interchangeable gratings covering the energy region 50-1500 eV and providing a flux of 4×10^9 - 5×10^{11} photons/sec/0.3A with a resolution of 1,000-10,000. The optical lay-out of the beamline is shown in the figure 1. The details of the optical elements are given in the Table-1 below**.** The first optical element of the beamline is a horizontally deflecting and vertically mounted toroidal mirror, TM_1, which accepts 2 mrad (horizontal) and 3 mrad (vertical) of the emitted bending magnet radiation. TM_1 focuses the light vertically on to the entrance slit, S_1, and horizontally on to the exit slit, S_2. The second mirror is a spherical mirror, SM, which is vertically deflecting and forms a convergent beam for the plane grating. After SM, the white light is diffracted by plane grating and the required wavelength is focused on the exit slit, S_2. Three interchangeable gratings, G_1, G_2 and G_3, of line densities 1200, 400 and 150 lines/mm are used to efficiently cover the whole energy region. The monochromatized light is focused on to the sample by horizontally deflecting and vertically mounted toroidal mirror, TM_2. The wavelength scanning is done by the pitch rotation of grating only and there is no need to move the slits.

TABLE-1 : Parameters of the beamline optical elements

Optical Element	**TM_1**	**SM**	**TM_2**	**G_1**	**G_2**	**G_3**
Deflection	Horizontal	Vertical	Horizontal	Vertical	Vertical	Vertical
Optical surface Size(mm^2)	900 ×50	300×20	250×20	180×15	180×15	180×15
Included angle (deg)	176	177	176	174.5	174.5	174.5
Groove density (lines/mm)	--	--	--	1200	400	150

Energy range (eV)	--	--	400-1500	150-600	50-225

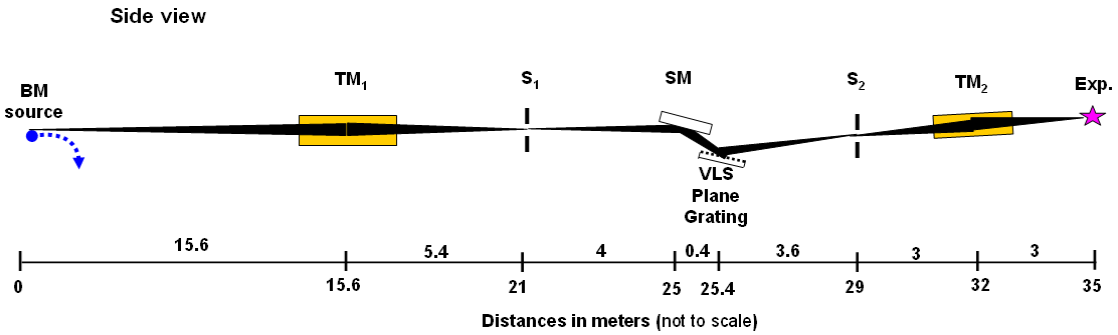

Figure 1: Optical lay-out of the beamline

The heights of all the optical elements with respect to the experimental floor are given below in the Figure-2 where **h=1405±10 mm**.

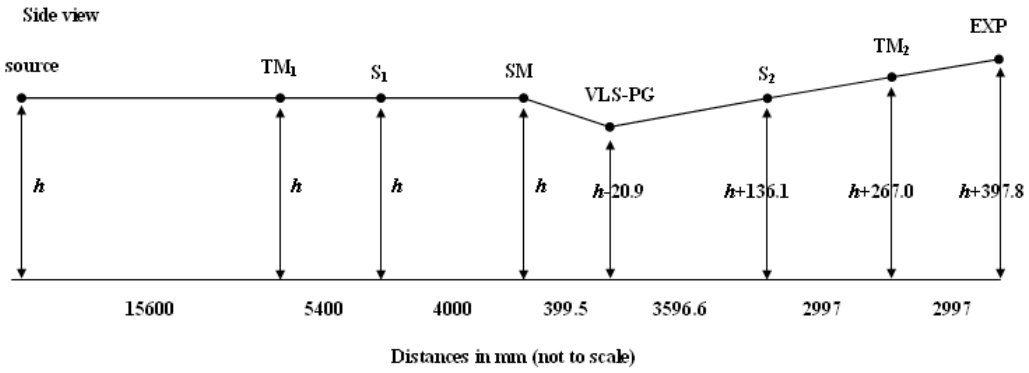

Figure 2: Schematic of change in vertical height of different optical elements relative to tangent point height ***h***.

2 Scope of supply

The scope of this tender consists of the engineering design, manufacturing, testing, delivery and installation of two mirror positioning system for pre and post focusing optics consist of vacuum enclosures, Mirror positioning mechanism, support and alignment structure with required electronics and software.

The supply consist of

- Complete engineering design of two mirror positioning system for pre and post focusing optics.
- Positioning and alignment mechanism for pre and post focusing mirrors

- Support structure with vibration isolation system and alignment mechanisms for both pre and post focusing optics.
- Vacuum enclosures for housing the pre and post focusing mirrors with their positioning mechanisms.
- Independent control system with computer interfacing to operate different stepper motors, and encoders.
- Electronics readout and appropriate controller and driver for stepper motors used.
- C/C++ and Labview 7.0 drivers with support to higher version.
- Measurement and qualification of optical mounts and mechanical movements.
- UHV test of the complete system and qualification of the vacuum after bake-out.
- Detailed drawings of complete Mirror positioning system
- Testing /qualification on manufacturer's site in presence of RRCAT representatives (pre-dispatch inspection)
- All spares required for trouble free operation of two years with complete details of their replacement procedure.
- Support and participation on site for installation and final qualification tests.
- **This call of tender does not include supply of x-ray mirrors.**

3 General Remarks

I. The system will operate at ambient temperature (26 ± 2 °C) and in UHV conditions (< 1×10^{-9} mbar pressure).
II. Supplier has to prepare and submit preliminary design/ concept report along with its offer.
III. The design must comply with UHV requirements and be bakeable up to 200°C
IV. Care should be taken in the design to ensure that the optics mechanism is not sensitive to floor as well as water flow induced vibrations.
V. Position of the optics should not be affected by tightening of the vacuum flanges or during vacuum pumping.
VI. No water joints should be directly exposed to vacuum side.

3.1.1 Definitions and co-ordinate system used

Through out this document we have followed the co-ordinate system as shown in the below figure for the optical elements.
Concerning mechanical movement, the following definition is applied in this document.

- **Resolution** is the minimum measurable increment which can be executed by the mechanics.

- **Repeatability** is the spread of values of final position obtained from repeated attempts to move to the same position.
- **Stability** is the largest deviation from the specified position during the specified time.

3.1.2 Pre-qualification for the bidder

The bidder must have an experience of fabricating at least two such systems of similar nature, otherwise bidder will be considered disqualified. List of users to who similar systems are supplied must be enclosed along with their addresses, emails and phone numbers.

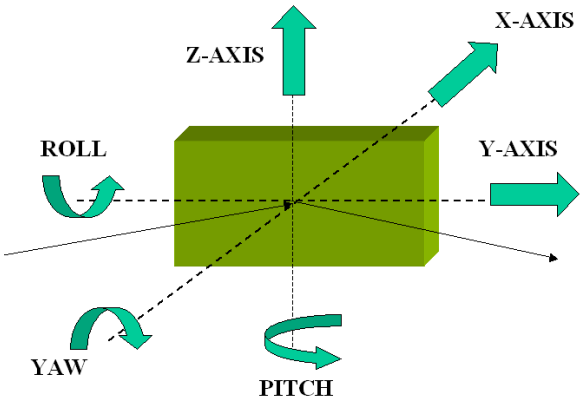

Figure 3: Schematics of co-ordinate system used in the document.

4 Technical Specifications

The pre focusing optics of the beamline is a **horizontally deflecting and vertically mounted toroidal mirror, TM1,** which accepts 2 mrad (horizontal) and 3 mrad (vertical) of the emitted bending magnet radiation. TM1 focuses the light vertically on to the entrance slit, S1, and horizontally on to the exit slit, S2 [see Figure 1]. The monochromatized light after the monochromator is focused on to the sample at experimental station by **horizontally deflecting and vertically mounted toroidal mirror TM2.** The two mirrors (TM1 & TM2) along with its holder and cooling system are **not included** in the scope of supply as it is going to be fabricated by M/S Seso France as per the following parameters.

TABLE-2: Parameters of pre and post focusing Toroidal mirrors.

SN	**Toroidal Mirror TM1 Parameters**	
1.	Substrate	Silicon
2.	Blank Size (LxW) [mm^2]	1000x80 [Tolerance ±0.5mm]
3.	Thickness [mm]	50mm

4.	Optically usable area [mm^2]	900 mm (L)× 50 mm (W)
5.	Mirror mounting	**Horizontal deflecting at 2 deg fixed incidence, see Figure1 above.**
6.	Distance from tangent point	15.6 meter
	Heat Load	
7.	Incident Power	60 Watt
8.	Axial Power density	96 W/ $mrad^2$
9.	Peak power at 2 deg angle	~13mW/ mm^2
10.	Absorbed Power	54 Watt
11.	Cooling arrangement	Side cooled design

SN	**Toroidal Mirror TM2 Parameters**	
1.	Substrate	Silicon
2.	Blank Size (LxW) [mm^2]	320 x 50 [Tolerance ±0.5mm]
3.	Thickness [mm]	50 mm
4.	Optically usable area [mm^2]	270 mm (L)× 25 mm (W)
5.	Mirror mounting	**Horizontal deflecting at 2 deg fixed incidence See Figure 1 above**
6.	Distance from tangent point	Define in Figure 1.

4.1 Mirror positioning mechanism

The two mirror positioning system will operate in ultra high vacuum of ≤ 1×10^{-9} mbar.

The mirror is to be mounted on a mechanism which permits it to be accurately positioned with respect to the incoming synchrotron beam. The mirror positioning mechanism shall be supported independently from the vacuum chamber.

Stable support structures are required to set whole system at the correct heights and angles with respect to synchrotron radiation beam.

Mirror positioning mechanism should have following movements and alignment provisions as listed in Table-3.

TABLE-3: Movements for TM1 and TM2

Movement	Range	Resolution	Repeatability	Actuator
Pitch	± 0.75 deg	**0.5 arc sec**	2 arc sec	Motorized/ encoded
Roll	± 1 deg	**1 arc sec**	5 arc sec	Motorized/ encoded
Yaw	± 1 deg	**1 arc sec**	5 arc sec	Motorized/ encoded

Tx	±10 mm	**1 µm**	5 µm	Motorized encoded
Tz	± 20 mm	**10 µm**	100 µm	Motorized
Ty	± 20 mm	**25 µm**	100 µm	

The positioning mechanism is to be protected from heating by scattered X-ray radiation. Any electronics, encoders, end-switches, motors or wiring associated with the positioning mechanism shall either be UHV and radiation compatible or be located outside of the vacuum chamber.

The positioning mechanism should be able to carry the weight of the mirror. Approximate weight of each mirror will be around 10 kg to 20 kg. **Pre mirror is water cooled,** so the design of positioning mechanism for pre mirror system should be capable of taking care of flow induced vibration of cooling water. The flow induced vibration should not affect the repeatability/resolution of the mirror system. Since the mirror along with its holder and cooling system is not part of the supply hence its design details will be provided at the purchase order stage of mirror positioning system**.**

All the materials used inside the vacuum chamber in this positioning mechanism, should be UHV compatible.

The adjustment of the mirror system as stated above shall be subjected to the coupled motion restriction as given below:

- While adjusting the pitch movement for ± 0.5 deg from ideal position; the setting of roll and yaw should not be disturbed by more than 5 arc seconds.
- While adjusting the roll movement for ±0.5º from ideal position; the setting of pitch and yaw should not be disturbed by more than 5 arc seconds

4.2 Ultra high vacuum chamber

Separate vacuum chamber suitable to operate the pre and post mirror with attached mechanisms in a vacuum of **1×10^{-9} mbar** shall be constructed and supplied by the manufacturer.

The vacuum vessel should be in two parts namely base plate and a rectangular enclosure. A suitable wire seal should be used between the base plate and rectangular enclosure. Also base plate should have groove for 'O' ring seal. Supplier should supply Viton 'O' ring of required dimensions. 'O'-ring groove is an additional sealing option.

All vacuum hardware, components and mirror manipulator should be UHV compatible. The ultimate vacuum in chamber shall be better than or equal to $1x10^{-9}$ mbar. Vessel should be bakeable to 200°C. Suitable heater assembly directly mounted on the vacuum vessel should be quoted separately. Suitable lifting eyes should be supplied. The leak rate of the chamber should be $\leq 5\times10^{-10}$mbar-lit/sec.

As per the design of mirror manipulator, two numbers of thermocouple feed through ports has to be located for **pre mirror system** and so thermocouples and electrical feedthroughs should be provided. Corresponding air-side male/female parts of connector/feedthrough should also be provided. Electrical

feedthroughs, limit switches etc. to be installed inside vacuum vessel should be UHV compatible. Provision should be made to take out the electrical signal from mirror surface. All the insulators used inside vacuum system must be UHV compatible.

Sputter ion pump (SIP) will be used to maintain the vacuum of the system which is not part of the supply. However the supplier will specify the suitable SIP and make necessary arrangement for mounting it to the vessel. Proper care should be taken in the design to give sufficient space for easy installation and maintenance of SIP. Proper support structure for SIP should be supplied by the supplier.

A tentative list of the required ports with flanges is given below. The list will be agreed upon during the design review process

The locations of the ports will be discussed during the design phase.

TABLE-4: Tentative list of different ports required in vacuum vessels.

Purpose		**Size (DN)**	Qty
Beam in		CF 152	1
Beam out		CF 152	1
Ion pump		CF 152/ CF203	1
Port to view Reflecting surface of mirror		CF 100	1
view port for mirror manipulator		CF63/CF40	
Spare Port right hand side of vessel		CF 40	2
Spare Port right hand side of vessel		CF 63	2
Spare Port right hand side of vessel		CF 63	1
Ion gauge port		CF 40	2
Venting port		CF 63	1
Ports for cooling line	In pre mirror system	CF 40	1
Temperature monitoring of mirror(s)		CF 40	2

- External dimensions of the vessel should be as small as possible provided easy access to each component and mechanism mounted inside.
- Lifting points must be available.
- All feedthroughs related to motors, encoders and others should be located preferably in the base plate.
- A flat reference surface for a precision leveling in both horizontal directions should be provided.

- Reference marks should be given externally showing the position of optical axis.
- Sufficient number of viewports should be given for visual examination of the optics.
- Appropriate arrangements must be used to reduce the thermal drift and amplification of the vibrations transmitted from the floor of the experimental hall.
- All the mounts inside the chambers must have sufficient stiffness in order to ensure their stability.
- Inner surface, welding joints, knife edges and overall cleanliness of the vessel must follow UHV compliance. Any deterioration caused by defying such norms will lead to rejection of the vessel during the test.

4.3 Support structure

The support and alignment structure for pre and post mirror system are required to position them in the beamline. The manual adjustments for the support are given in the following table

TABLE-5: Alignment parameter for support structure

Adjustment	Range	Resolution
X	±15 mm	0.2 mm
Y	±15 mm	0.2 mm
Z	±20 mm	0.2 mm
Pitch	±1°	10 arc sec (48 μrad)
Roll	±2°	10 arc sec (48 μrad)
Yaw	±1°	10 arc sec (48 μrad)

This support and alignment structure for vacuum vessel may be a granite or concrete base rigidly fixed to the floor. It should limit the amplification of ground vibrations transmitted to the system in the frequency range 0 – 55 Hz, and will possess no normal vibrational modes in the frequency range 0 – 30 Hz and at 50Hz. Vibrations of the vacuum vessel should be uncoupled from those of the mirror mechanism.

- Supplier may use granite or any rigid structure, provided, whichever is the best for stability issue.
- Any tightening or locking arrangement should not affect the optics position.

4.3.1 External alignment marks

The design of the system should provide an easy means to align the optical components relative to synchrotron beam. Namely, the vacuum vessel should have provision to mount survey monuments at least at three or four points. The distances between these points shall be maximised and their position relative to X-ray beam shall be known with an accuracy of 100 μm. A reference mark shall be positioned on the top and on the side of the vacuum chamber, indicating the nominal beam height when all adjustments are in the mid position. The detailed layout of the reference marks will be mutually agreed during the project design phase.

Supplier should mention the detail alignment procedure.

The reference marks should be placed in such a way that the relative position of the active element with respect to these marks can be accurately measured (required precision equal to the positioning tolerances) when the chamber are open or during the assembling process.

The supplier will provide measured data for the location of all fiducial points with respect to the, mirrors and other crucial mechanical references such as the mirror rotation axis.

4.4 Control system

All the motorized motions of Mirror positioning system with feedback loop of encoder reading will be controlled/ monitored through a PC using Windows 7. Labview 7.0 and C/C++ drivers required for different controller/ driver/ readout units with detail protocols must be provided. Details of cable length etc. will be discussed during the design phase.

4.5 Vacuum

All the chambers with mechanics should be bakeable upto 200°C. Baking system specially sheath heater for both vacuum chamber is a part of supply. Baking controller and temperature sensors should be quoted optionally.

All vacuum vessels must achieve <1x 10^{-9} mbar vacuum along with their mechanics.

The chambers should be filled with dry nitrogen before shipping.

The leak rate of complete mirror system should not exceed 5×10^{-10} mbar liters per second.

RGA tests should show that the sum of the partial pressures of gases having a mass **>46 AMU** does not exceed 10^{-11} mbar in all chambers.

Vacuum tests shall be performed both with and without water circulating through water-cooled components.

Leak testing

The detection should be made with a suitable helium leak detector. The pumping system of the leak detector should be composed of oil free pumps, and the detector must not introduce any contaminant into the vacuum vessel. The maximum overall leak rate tolerable for the vacuum vessel is 5 x 10^{-10} mbar.l.s^{-1}.

Vacuum and leak testing will be performed at factory and supplier will make necessary arrangements for that purpose. Similar checks will be carried out at user site after delivery.

5 Compliance chart

Supplier must provide the compliance of the major functional specifications in the format described in Annexure-1. In this table supplier can incorporate some other parameter which they feel essential for achieving the desired performance of the item. The item should full fill the technical requirements mentioned in this document.

6 Spares and accessories

Essential spares 1) stepper motors 2) encoders 3) cable connectors and pins 4) motors drivers 5) vacuum sealing wire **must be quoted separately.** All optional accessories and spares required for smooth operation of whole system for next two years should also **be quoted separately** (please list the spares separately).

7 Approval of design

The preliminary design shall got be approved by RRCAT before finalizing the actual design of the system. Specifications including make and model number of all standard parts i.e. encoders, edge welded bellows, stepper motors etc. shall got be approved by RRCAT. However this approval should not be considered as a relaxation from meeting all the specifications of the final product.

8 Metrology and Test Plan

Supplier should ensure fully characterization of all the functional features of the delivered system. For each item or group of items, the list of the required measurements and tests, as well as the characterization methods, should be finalized and agreed upon at the end of the design reviews before the fabrication will start.

9 Factory, onsite tests and Acceptance Criteria

- Supplier has to prepare and submit the detailed test plan (along with instruments used and methods) for each and every parameter as per relevant international standards and get it approved from the purchaser.

- The whole mirror positioning system should be assembled in final form for vacuum and mechanical tests. The whole system in the assembled form should be leak proof ($< 5 \times 10^{-10}$ mbar l/s) and tested in vacuum ($\leq 1 \times 10^{-9}$ mbar) by the supplier at their factory site. RGA spectrum of vacuum chamber should be free of hydrocarbon contaminates (AMU>46). Supplier shall submit the test report of ultimate vacuum and leak testing to the purchaser.

- The supplier shall submit test results of all physical tests (movements range, resolution, repeatability, etc) and alignment as per relevant international standards.

- All physical tests shall be repeated both in factory and at purchaser's site in presence of RRCAT representative. The detailed tests and acceptance criterion remain as per the specifications given above.

- The manufacturer shall provide the facilities and instrumentation, to perform all relevant tests to ensure compliance with the specifications.
- Engineers from original manufacturer will participate in the installation of mirror positioning system at the RRCAT site and will ensure the repeatable functional operation of the system.

10 Documentations

All documentation must be in English. Both hard and soft copies must be provided

Supplier will provide complete alignment protocol of all the key components and in turn of complete system for achieving the desired goal.

Supplier will give all the test reports of mechanism along with instrument details used for testing.

The manufacturer will provide RRCAT with a set of detailed drawings in electronic format compatible with **AutoCAD,** and indicating the overall dimensions of the mirror system, its support and methods of fixation to the floor and the beam tube, and any useful information to set up and maintain the instrument.

Electrical cable details and their connection to the feedthroughs should be provided.

Detail documentation of encoder readouts, motor controller and driver units with proper details of their PC interfacing protocols.

Detail procedure of optics installation

C/C++ driver and LabVIEW 7.0 VIs with complete details for easy integration with user design software.

Complete user manual.

11 Packing and Shipping

All the vessels and their support structures will be packed properly for shipping. Electronics, controllers, accessories and spares should be individually packed and properly sealed for shipping. It is responsibility of the supplier to mount and install whole mirror mechanism system at RRCAT. The supplier shall demonstrate performance and operation at RRCAT after installation.

12 Ground Preparations

The supplier should give details of installation and utility requirements at site at the tender stage. The supplier should arrange the special instruments/equipments, if any, required for RRCAT site testing.

13 Guarantee

The complete mirror system will be under guarantee of supplier for one year from the date of testing and commissioning at RRCAT.

Annexure-1: Compliance chart to be filled by supplier

S.N.	Parameter	Values	Suppliers values	Remarks (Supplier Justification for any deviation from desired value)
1.	Mirror positioning system with different movements defined in Table 3,	See 4.1		
2.	Coupling errors of pitch, roll, and yaw for ±0.5º movement should be less than 5 arc sec	See section 4.1		
3.	UHV vessels along different feedthroughs for pre and post mirror mechanism.	See section 4.2		
4.	Support structure to set the whole mirror system at SR beam height for both pre and post mirror system with vibration isolation arrangement	Required		
5.	UHV compliance for all the components	Required		
6.	Survey and reference marks on mirror vessels with proper referencing	Required		
7.	Electronic driver and control system of all the motorized motions with feedback loop of encoders, all compatible with Windows 7 along with user friendly software	Required		
8.	LabVIEW and C/C++ drivers of different controller/ driver/ readout units with complete protocols	Required		
9.	Sheath heater for both vacuum chamber	Required		
10.	Essential spares such as stepper motors, encoders, cable connector and pins, motor driver, metal sealing wire required for two years of trouble free operation.	Required		
11.	List of users to whom similar system has been supplied with verifiable addresses	Required		