

Technical specifications of high vacuum reflectometer for soft x-ray beamline on Indus-2

Contents

- 1 Purpose**
- 2 Scope of supply**
- 3 General Remarks**
Definitions and co-ordinate system used.
- 4 Indus-2 Source**
- 5 Description of Soft X-ray Beamline**
- 6 Reflectometer: Technical specifications**
 - 6.1 Scheme of Reflectivity measurement
 - 6.2 2-Axis goniometer
 - 6.3 x-y-z sample scanning stages
 - 6.4 Sample holder
 - 6.5 Detector arm
 - 6.6 Vacuum chambers and supports
 - 6.7 Anti scattering slit
 - 6.8 Motor and encoders
 - 6.9 Electrical wiring
 - 6.10 Support structure and alignment marks
 - 6.11 Control system
- 7 Vacuum.**
Leak testing
- 8 Compliance chart**
- 9 Spares and accessories**
- 10 Approval of design**
- 11 Test Plan**

12 Factory, onsite tests and Acceptance Criteria

13 Documentations

14 Packing and Shipping

15 Ground Preparations

16 Guarantee

Check list (before submitting quotation):

Annexure-1: Compliance Chart to be filled by supplier

1 Purpose

This document consists of technical specifications for the design and construction of a high vacuum reflectometer for the soft x-ray beamline on Indus-2 synchrotron source. A typical list of items to be supplied and the required technical specifications are specified in the document.

2 Scope of supply

The scope of this tender consists of the engineering design, manufacturing, testing, delivery and installation of high vacuum reflectometer comprising of a in vacuum goniometer, X-Y-Z sample scanning mechanism, vacuum enclosure, vacuum pumps, support structure, and control system

Items to be supplied

- Engineering design of the high vacuum reflectometer with 2 rotation stages and X-Y-Z sample scanning stages.
- Alignment mechanism for the reflectometer with incident synchrotron radiation.
- Support structure and alignment mechanisms.
- Anti scattering slits at the entrance port of the reflectometer.
- Vacuum enclosure along with suitable turbo molecular pump and oil free backing pump.
- All electrical and other feedthroughs required for reflectometer operation.
- Independent control system with computer interfacing to operate goniometer , X-Y-Z sample scanning stages and a slit system.
- Position readout, appropriate controller and driver for motors and encoders used.
- C/C++ drivers and Labview drivers with support to 7.0 and higher version for Windows XP and Vista
- Vacuum test of the complete system.
- Design layout, assembly and fabrication drawings of the reflectometer system including slits, support structure and alignment mechanism.

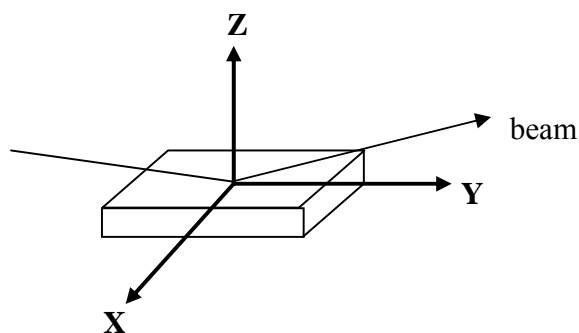
- All spares required for trouble free operation of two years with complete details of their replacement procedure.

3 General Remarks

- I. The system will operate at room temperature and in high vacuum ($\leq 1 \times 10^{-6}$ mbar pressure).
- II. The design must comply with high vacuum requirements and be bakeable up to 150°C
- III. Ambient temperature stability in the beamline area is $\pm 2^\circ\text{C}$.
- IV. Position of the sample mounted on goniometer rotation axis should not be affected by tightening of the vacuum flanges or during vacuum pumping.
- V. **Supplier with past experience of fabrication of similar equipments or beamline monochromator to at least two synchrotron facilities will only be eligible for this tender bid.**

Definitions and co-ordinate system used.

Through out this document we have followed the co-ordinate system as shown in the below. Y direction is the synchrotron light direction.



4 Indus-2 Source

Indus-2 is a 2.5 GeV Synchrotron radiation source with a critical wavelength of 2 Å and operating with 300 mA of ring current. The bending magnet field is 1.502 Tesla. Source parameters for the proposed bending magnet port are $\sigma_x=0.203$ mm, $\sigma_y=0.272$ mm, $\sigma_x'=0.323$ mrad, $\sigma_y'=0.062$ mrad. (X for horizontal and Y for vertical).

5 Description of Soft X-ray Beamline

A constant included angle VLS-PGM design is adopted for the soft x-ray reflectivity beamline on port number BL-3 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 $4 \times 10^9 - 5 \times 10^{11}$

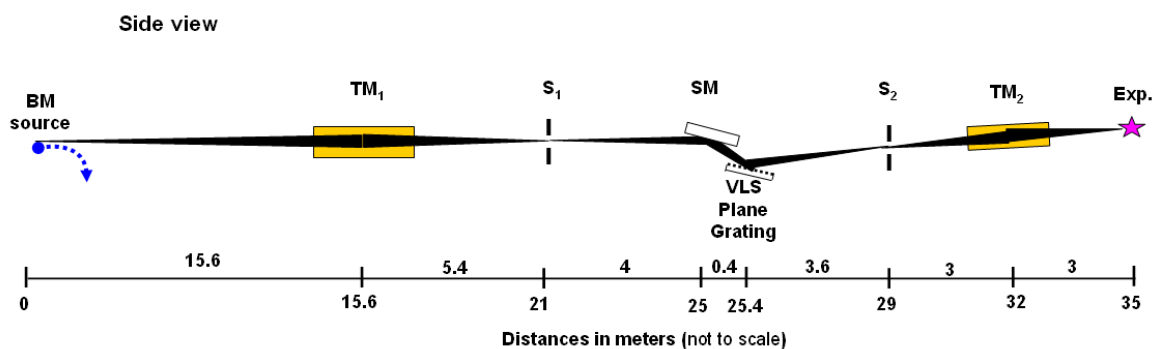


Fig.1. Optical lay-out of the beamline

photons/sec/0.3Å with a resolution of 1,000-10,000. The optical lay-out of the beamline is shown in the **figure 1**. The first optical element 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. 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, S₂. Three interchangeable gratings, G₁, G₂ and G₃, 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, TM₂. The wavelength scanning is done by the pitch rotation of grating only and there is no need to move the slits.

The heights of all the optical elements with respect to the experimental floor are given in figure 2 where **$h=1405 \pm 10$ mm**

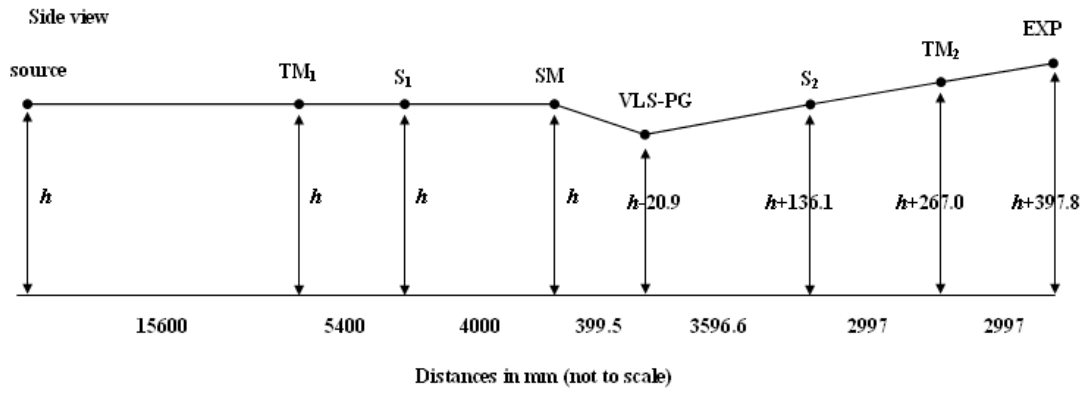
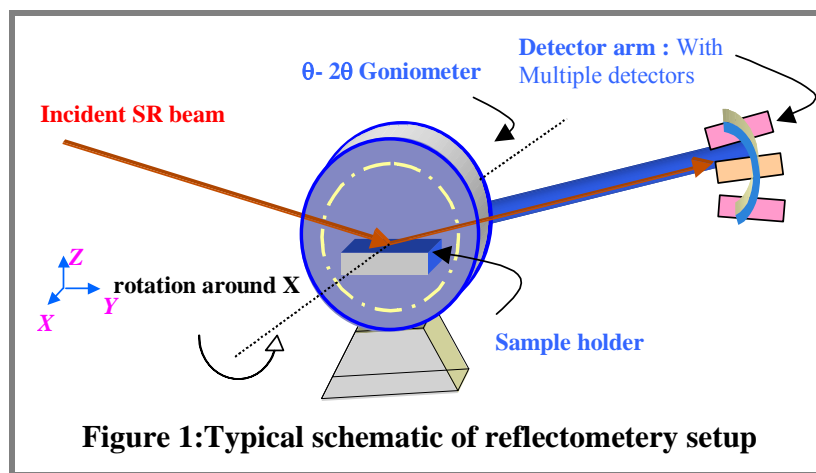


Figure2: Vertical height h of the tangent point and thereafter relative change in vertical position of different optical elements.

6 Reflectometer: Technical specifications

Proposed reflectometer is required for reflectometry experiments with disk or parallelepiped-shaped samples (Si wafers or mirrors for example). It will be used for reflectivity experiments in the wide angular range of grazing incidence to normal incidence region. The device consists of 3-axis sample scanning stages and 2-axis rotary stages. A typical scheme of reflectometry setup is presented in *Figure 1*. Incident SR beam is along the Y axis.



The proposed reflectometer will operate at room temperature and in high vacuum (HV) environment, therefore vacuum inside the chamber is required to be **better than 1×10^{-6} mbar with all mechanics inside the enclosure.** Details of different movement and scanning range are described below.

6.1 Scheme of Reflectivity measurement

Sample with given dimensions (**Table 1**) will be mounted on x-y-z scanning stages and those in turn will be mounted on a coaxially mounted 2-axis goniometer. These translation stages will be used to accomplish surface scanning of the sample with incident synchrotron beam. These stages along with the sample will be mounted on 'theta' stage of goniometer which will rotate the sample for angle versus reflectivity measurements. '2-theta' stage of the goniometer will hold multiple detectors like silicon photo diode, channeltron, CCD, wire detector etc. During a scan either of these detectors can be set for reflectivity/ diagnostic measurements

Table 1: Details of sample dimension

Weight	Size (max)			dia	Material
	L	W	T		
5 Kg max.	300 mm	100 mm	50 mm	300 mm	Si wafer, Glass, zerodour etc.

6.2 2-Axis goniometer

A precision coaxially mounted 2-axis goniometer is required for rotary motion of sample and detectors. Rotation axis of the goniometer will lie in horizontal plane (*along x-axis*). Both rotation axis should be independently movable. The off axis load posed by sample (along with x-y-z- scanning stage) and detector should be taken into account to maintain the angular accuracy and stability for full angular range. The repeated motion of sample and detector *against* and *in-line* of gravity should not cause backlash error greater than 0.001° . In vacuum reference positioning and encoding arrangements should be provided with all necessary arrangements. Details of goniometer specifications are given in Table 2. The circle of confusion for the goniometer should be less than 50 micron.

Table 2: Goniometer and X-Y-Z scanning stages

Item	Purpose	Size	Range	Resolution	Accuracy	Straightness	Remark
Goniometer	θ stage: for sample rotation		$\pm 180^\circ$	$\leq 0.001^\circ$	$\leq 0.005^\circ$		Encoded+ Limit & ref. switch
	2θ stage: for detector rotation		-10° to 200°	$\leq 0.001^\circ$	$\leq 0.005^\circ$		Do
Translation stages	Cartesian scan	x	± 75 mm	$2\mu\text{m}$	$10\mu\text{m}$	$< 10\mu\text{m}$	Do
		y	± 75 mm	$2\mu\text{m}$	$10\mu\text{m}$	$< 10\mu\text{m}$	Do
		z	± 25 mm	$1\mu\text{m}$	$5\mu\text{m}$	$< 10\mu\text{m}$	Do

The goniometer rotation axis will be perpendicular to incident synchrotron beam and will pass through horizontal incident beam plane. To maintain this condition all the necessary adjustment must be provided.

6.3 x-y-z sample scanning stages

Any location of sample surface is subject to reflectivity measurement, hence it is proposed to mount the sample on a x-y-z translation mechanism. Range required for x-y-z scan is specified in

Table 2 Sample will be mounted on this mechanism with the help of properly designed holder which can hold samples of different sizes.

6.4 Sample holder

Sample holder can accommodate disk-shaped samples such as Si wafers or parallelepiped shaped mirrors. As a guideline, sample will not be directly installed onto the mechanics but fixed into a removable holder that in turn will mount on scanning mechanism. For any kind of electrical measurement, sample should be **electrically isolated** from the rest of the body.

6.5 Detector arm

Different type of detectors like photodiode, channeltron, CCD or wire type detectors are planned to mount on a detector arm. However the maximum size of a single detector is around $5 \times 5 \text{ cm}^2$ and the weight is around 200 g. For near normal incidence measurement (say 85° for sample and 170° for detector), Si photodiode/ channeltron will be used having $2 \times 2 \text{ cm}^2$ max size. Mounting of multiple detectors must allow to measure the normal incidence reflectivity in $85\text{-}89^\circ$. Length of the detector arm from the centre of the goniometer should be adjustable in the range of 150-250mm.

6.6 Vacuum chambers and supports

Vacuum vessel should enclose the 2-axis goniometer and sample scanning stages. Viton sealed opening flange should be provided for sample loading/ unloading purposes. This opening should be big enough to access any mechanics/ wiring/ motors/ encoders etc for maintenance purpose.

The vessel material must be **UHV** compatible, however the ultimate vacuum in the vessel with all the mechanism in action should be better than $1 \times 10^{-6} \text{ mbar}$. The ultimate vacuum level should be achievable without baking. Supplier should provide a suitable turbomolecular pump with oil free baking pump capable to achieve the ultimate vacuum without baking within 5-6 hour pumping time.

Lifting points must be available on the vessel.

A flat reference surface for a precision level should be provided. This surface should be parallel to goniometer rotation axis with $\leq 10 \text{ arcsec}$ accuracy. Reference marks should be included externally showing the position of the rotation axis. These marks should be accurate to $\pm 0.1 \text{ mm}$ or better.

A tentative list of requested flanges is given below, however the exact number and sizes will be fixed during the design review. Extra ports, if required will be added during the design review.

TABLE 3: LIST OF TYPICAL FLANGES REQUIRED

S.No	Type	Description	Qty.
1.	Vessel Material	SS304L stainless steel	
2.	Size of beam entrance	DN63CF	1
3.	Size of beam exit	DN63CF	1
4.	Size of vacuum gauge	DN40CF	1
5.	Size of view port	DN100CF	2
		DN40CF	2
6.	Turbo Molecular Pump port		1

TABLE 4: REFLECTOMETER VESSEL ALIGNMENT MOVEMENTS

Movement	Range	Actuator	Resolution
Z (vertical)	± 20 mm	Manual adjustable	≤ 1 mm
X (horizontal)	± 15 mm	Manual adjustable	≤ 1 mm
Y (longitudinal)	± 15 mm	Manual adjustable	≤ 1 mm

6.7 Anti scattering slit

Locations of the anti scattering slit in the reflectometer will be near to entrance beam port of the vacuum vessels. These slits will have a continuous opening aperture in the vertical (Z) direction. These slits will operate in high vacuum environment. Slit should be mounted on a proper support structure and have a provision to align it with synchrotron beam height. Vertical position of the centre of the slit assembly should be motorized. Mounting of the slit blades should be electrically isolated with rest of the body for any electrical measurements. Hence necessary electrical feedthroughs should be provided.

Slit blades will have a working length of **10mm** in the horizontal direction. The vertical opening will be adjustable from 0 micron to 2 mm. The slit will have to be made such that the blades are horizontal and parallel with the precision indicated in the Table 5 below.

Table 5: Slit setting parameters

Slit	Stability	Resolution	Accuracy	Amplitude	Remarks
Opening	2 μ m	≤ 2 μ m	10 μ m	0 μ m – 2 mm	Motorized, encoded

6.8 Motor and encoders

Motors mounted inside the vacuum chamber should be UHV compatible. All motorized components shall have adjustable limit switches for each motorized degree of freedom in addition to hard stops for each motorized degree of freedom.

Motors and encoders should withstand the bake-out of the chamber at least to 150°C.

6.9 Electrical wiring

Every electrical wiring, should be protected from the Synchrotron radiation by careful routing inside the vacuum vessel and / or with efficient radiation shielding. Any radiation shielding should be easily removable to enable access to the wiring. All wires will be electrically insulated with radiation resistive plastics such as Kapton®. All electrical connections and wiring shall withstand baking to 150°C for 24h.

6.10 Support structure and alignment marks

Support structure of goniometer and vacuum vessel should be rigid with necessary alignment movements. Vibrations of the vacuum vessel should be uncoupled from those of the goniometer rotary stage.

The goniometer should be mounted inside vacuum chamber on a support structure with manual adjustment provision defined in Table 6. If required, the goniometer alignment can be linked with the main vessel alignment system. In this case, sufficient movement range and resolution in the vessel alignment mechanism should be provided for setting the goniometer rotation axis within 10 micron accuracy, with respect to synchrotron beam.

An alignment protocol should be submitted in order to align the sample, goniometer rotation axis and the vessel with respect to the incoming beam. A list of dedicated instrument should be submitted in order to perform this task.

TABLE 6: GONIOMETER SETTING PARAMETERS

<i>Adjustment</i>	<i>Range</i>	<i>Resolution</i>
X	±10 mm	10 µm
Y	±25 mm	
Z	±30 mm	
Pitch	±2°	
Roll	±2°	
Yaw	±2°	

Reflectometer vacuum vessel and the goniometer support structure 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 should 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 for goniometer and whole reflectometer assembly.

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

6.11 Control system

All the motorized motions of reflectometer with feedback loop of encoder reading should be controlled/monitored through a PC using Windows 7.0. 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.

7 Vacuum.

Suitable turbo molecular pump with a oil free backing pump capable to obtain vacuum better than 1×10^{-6} mbar in 5-6 hour pumping time is also a part of the supply.

All the chambers with mechanics should be bakeable upto 150°C. Baking system (heater, temperature controller & sensors) should be part of supply

The complete reflectometer should have a leak rate which does not exceed 5×10^{-10} mbar liters per second of He.

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

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 5×10^{-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.

8 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. **Supplier is encouraged to propose a better cost effective design along with the justification for proposed modifications.**

9 Spares and accessories

Essential spares 1) stepper motors 2) encoders 3) cable connectors and pins 4) motors drivers 5) Viton O ring 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)

10 Approval of design

The preliminary design should 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, stepper motors etc. should be approved by RRCAT.

11 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 during the design review and before the start of the fabrication.

12 Factory, onsite tests and Acceptance Criteria

- The whole reflectometer 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 ($\sim 1 \times 10^{-6}$ 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 should show results of all physical tests (speed/accuracy/repeatability, etc) and alignment of reflectometer system as per relevant international standards before dispatching the material. All movements (as per table-1 to 6), range, resolution and accuracy as per the relevant international standard should be physically tested both in factory and purchaser's site. The detailed tests and acceptance criterion remain as per the specifications given from serial no 6-11.
- 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 reflectometer at the RRCAT site and will ensure the repeatable functional operation of the system.

13 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 should give all the test reports of mechanics along with instrument details used for testing.

The manufacturer should provide RRCAT with a set of detailed drawings in electronic format compatible with **AutoCAD**, and indicating the overall dimensions of the reflectometer, 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.

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

Complete user manual.

14 Packing and Shipping

All the vessels and their support structures will be packed separately 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 reflectometer system at RRCAT. The supplier shall demonstrate performance and operation at RRCAT after installation.

15 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.

16 Guarantee

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

Check list (before submitting quotation):

1	The bidder is original manufacturer or authorized dealer/ representatives.	Yes / No
2	Authorization certificate attached. (If you an authorized dealer)	Yes / No

3	For manufacturing expertise list of similar system with the name of installations and contact person attached.	Yes / No
4	Factory Acceptance Test (FAT) Plan submitted.	Yes / No
5	Warranty for a minimum period of twelve months from the date of installation accepted.	Yes / No
6	Supplier will provide service of installation, commissioning and testing of reflectometer setup at RRCAT, Indore (India) without any additional cost.	Yes / No
7	All relevant documents providing asked technical information of system are provided along with offer.	Yes / No
8.	Cost for all spares and accessories is included.	Yes / No

Signature and seal of authorised signatory of the company

(Name and date)

Annexure-1: Compliance Chart to be filled by supplier

Table: Compliance chart

S.N.	Parameter	Values	Suppliers values	Remarks (Justification for any deviation from desired value)
1.	Table 1, Sample size and load	(See section 6.1)		
2.	Table 2, goniometer and X-Y-Z Scanning stage.	(See section 6.2 & 6.3)		
3.	Table 4, Reflectometer vessel alignment	(See section 6.6)		
4.	Table 5, Slit adjustment	(See section 6.7)		
5.	Table 6, goniometer alignment parameters	(See section 6.10)		
6.	Vibration isolation arrangement in slit and Reflectometer vessels	Required.		
7.	Turbo molecular pump with oil free backing pump to get 1×10^{-6} mbar pressure within 5-6 hour period	required		
8.	UHV Compliance for all the components			
9.	Survey and reference marks on goniometer and reflectometer vessels with proper referencing	Required (See section 6.10)		
10.	Driver and Control system of all the motorized motions with feedback loop of encoders using Windows 7 platform along with user friendly software	Required (See section 6.12)		
11.	Labview and C/C++ drivers of different controller/ driver/ readout units with complete protocols	Required		
12.	Baking system with heater, temperature controller and sensors for complete assembly	Required		