Technical Specifications and Conceptual Design for the Taiwan-Anglo Coherent Diffraction Endstation (TACoDE)

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## Contents

1 Introduction and Scope ............................................. 5
   1.1 Introduction .................................................. 5
   1.2 Scope ......................................................... 5
   1.3 Deliverables .................................................. 6
   1.4 Reports and Documentation ................................... 6
   1.5 Timescales .................................................... 7
   1.6 Guarantee ..................................................... 8

2 Conceptual Design .................................................. 9
   2.1 Required Properties .......................................... 9
   2.2 Beamline Characteristics of the TPS beamline 41A .......... 10
   2.3 Outline ....................................................... 10
   2.4 Definitions and References .................................. 11
      2.4.1 Co-ordinate System ...................................... 11
      2.4.2 Definitions ............................................. 12
   2.5 Diffractometer Axes, Motions and Mnemonics ................ 12
      2.5.1 Motion hierarchy ........................................ 14
      2.5.2 Principle diffractometer axis ............................ 14
      2.5.3 Sample translations ..................................... 14
      2.5.4 In-vacuum Gamma Rotations ............................. 15
      2.5.5 In-vacuum Polarisation Analyser (PA) .................. 15
      2.5.6 Table Motions ........................................... 16
   2.6 Realisation of Diffractometer ................................ 20
      2.6.1 Vacuum Chamber and Table ............................... 20
      2.6.2 del Rotation ............................................ 20
      2.6.3 th rotation ............................................. 22
      2.6.4 sx, sy, sz translations ................................ 22
      2.6.5 Cryostat ............................................... 22
      2.6.6 gamma rotations ....................................... 26
      2.6.7 2D Detector ............................................. 26
      2.6.8 Polarisation Analyser (PA) ............................. 28
   2.7 Loadlock ....................................................... 30
   2.8 In-vacuum mounting points .................................... 31
   2.9 Ports on vacuum chamber ..................................... 31
      2.9.1 Main Chamber ........................................... 31
      2.9.2 Delta rotation .......................................... 31
2.10 Alignment procedure ............................................. 31
2.11 Required performance of key items .......................... 35
  2.11.1 Diffractometer System ................................... 35

3 General Mechanical Specifications .................................. 39
  3.1 Fasteners and Fittings ....................................... 39
  3.2 Mountings and Stands ......................................... 39

4 Electrical System, Motor and Controls .......................... 40
  4.1 Motors .................................................. 40
  4.2 Limit Switches ............................................ 40
  4.3 Encoders ................................................ 40
  4.4 Cabling .................................................. 41
  4.5 Electrical Drawings ....................................... 41

5 Vacuum .......................................................... 43
  5.1 General .................................................. 43
  5.2 Vacuum Equipment ......................................... 43
  5.3 Materials for UHV use ..................................... 43
  5.4 Machining and Fabrication .................................. 44
  5.5 Marking and Labelling ..................................... 45
  5.6 Handling and Packing ...................................... 46
  5.7 Bakeout ................................................... 46
  5.8 UHV Cleaning ............................................. 47
    5.8.1 Health and Safety .................................... 47
    5.8.2 Comments on this Specification ......................... 47
    5.8.3 General Procedures ................................... 47
    5.8.4 Standard Cleaning Procedure for Stainless Steel Com-
         ponents ................................................. 49
    5.8.5 Alternative Cleaning Processes for Stainless Steel .... 50
    5.8.6 Cleaning Procedures for Copper Components ............ 50
    5.8.7 Cleaning Procedures for Vacuum Bellows ................ 50
    5.8.8 Ceramics ............................................ 51
    5.8.9 Aluminium Components ................................ 51
    5.8.10 Assemblies and Sub-assemblies ......................... 52
6 Packing and Delivery 53
   6.1 Delivery .................................................. 53
   6.2 Packing .................................................. 53
   6.3 Shipped Condition ...................................... 53

7 Quality Assurance and Testing 54
   7.1 Quality Assurance Testing ............................. 54
   7.2 Material Traceability ................................... 54
   7.3 Additional documents to be supplied ................ 54
      7.3.1 With the shipment of each assembly .......... 54
      7.3.2 With the shipment of the final assembly .... 54
   7.4 General arrangement for tests ....................... 55
   7.5 Factory acceptance tests ............................. 55
      7.5.1 Vacuum Tests ..................................... 56
      7.5.2 Mechanical ........................................ 56
      7.5.3 Electrical Acceptance Tests .................. 57
   7.6 Delivery Acceptance Tests ............................ 57

8 Appendices 58
1 Introduction and Scope

1.1 Introduction

The soft x-ray diffractometer system will be specified and ordered by the National Synchrotron Radiation Research Center (NSRRC), Taiwan working in collaboration with Durham University, UK. The contract for the design and construction of the diffractometer will lie entirely with NSRRC. Delivery of the diffractometer will be to NSRRC.

The diffractometer will be used to study the magnetism and other long range correlations in single crystals and multilayers. The system will facilitate coherent resonant diffraction at the soft absorption edges, typically those of the transition metal $L$ edges. The system will be used with synchrotron radiation light, provided on the beamline 41A on the Taiwan Photon Source (TPS) at NSSRC.

Soft x-ray diffraction utilises x-rays in the energy range 500-2000 eV (0.6-2.5 nm). A sample is manipulated at a fixed spatial point coinciding with the incident x-ray beam, such that the x-rays are diffracted from the sample. A second arm comprises a detector system in order to detect the scattered x-rays. The use of low energy x-rays demands that the entire path of the x-rays from beamline to sample to detector is within a vacuum.

1.2 Scope

Tenders are invited for a three-circle, double detector, diffractometer that will act as a self contained x-ray beamline end station. The diffractometer will be used with a helium flow cryostat (not in tender) which will form the sample manipulation arm. We require a completely assembled and mechanically tested instrument, comprised of the three axis, motors, $x,y,z$ sample stage, polarisation analyser and 2D detector stage, and motorised table all of which are described in more detail below. The diffractometer will be supplied complete with vacuum chamber, to be used with an agreed set of pumping equipment.

The contract will cover the design, technical drawings, test, delivery and installation.
1.3 Deliverables

The soft x-ray diffractometer system to be delivered will comprise:

1. A UHV compatible diffractometer comprising a flow cryostat sample rotation, with \( xyz \) stage, two detector rotations one with a polarisation analyser and one for a 2D area detector (free issue).

2. All motors, limit and home switches, and encoders where deemed necessary

3. All electrical and mechanical connections.

4. UHV vacuum vessel.

5. Adjustable motorised support table with rotation, horizontal translation and adjustable feet for the diffractometer and vacuum vessel.

6. Sufficient parts to guarantee operation of the system with minimum down-time for a period of at least 2 years from the date of final acceptance.

7. All drawing, manuals and associated documentation.

8. Shipping, installation and testing.

The diffractometer system is to be supplied ultra-high vacuum cleaned and conditioned (see section 5) and in a state ready for immediate installation. It is to be shipped as described in section 6.

1.4 Reports and Documentation

The following documents will be provided by the supplier:

1. Design review documentation.

2. Factory and site acceptance test procedure(s).

3. Factory and site acceptance test reports including full motion test results.
4. Full support documentation for all items of equipment, including all installation, operation and maintenance manuals, including components supplied by a third party.

5. Two full sets of drawings for all equipment supplied to NSRRC.

6. Electronic set of drawings and solid model.

7. A list of recommended spare items and any spare parts included within the tender. The costs of such items must be clearly identified whether included in the tender or to be purchased separately.

8. Safety report.

9. Quality assurance documents for the completed device with copies of all specified material certificates, details of all quality control checks and intermediate test results.

All drawings, reports and documentation must be provided in full and in English.

1.5 Timescales

NSRRC requires the following timescales to be met:

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Months after start of contract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of contract</td>
<td>0</td>
</tr>
<tr>
<td>Kick-off meeting</td>
<td>1.0</td>
</tr>
<tr>
<td>Final design review</td>
<td>5.0</td>
</tr>
<tr>
<td>Factory acceptance tests</td>
<td>13</td>
</tr>
<tr>
<td>Delivery and on-site acceptance tests</td>
<td>15</td>
</tr>
</tbody>
</table>

The supplier must confirm that they can meet these timescales.

The tenderer needs to present a proposal that complies with the specifications and requirements of TACoDE in the kick-off meeting held at in NSRRC. This proposal must be approved by NSRRC.

The tenderer needs to present a final design with the details of design and construction process. The final design report must be approved by NSRRC, prior to commencing with manufacturing.
1.6 Guarantee

The equipment shall be guaranteed for 18 months following the date of delivery or 12 months from the date of final acceptance, whichever is later. In addition the system should be supplied with sufficient parts for 24 months of use from the date of final acceptance tests as specified in section 7.5.
2 Conceptual Design

This section covers the specifications and conceptual for the Taiwan-Anglo Coherent Diffraction Endstation (TACoDE). Electronic copies of the solid model forming the conceptual design can be provided on request. The endstation is to be situated on beamline 41A on the Taiwan Photon Source. This will be the second endstation and be installed downstream of a Resonant Inelastic X-ray Scattering (RIXS) endstation.

The endstation is to provide an environment for soft x-ray diffraction, in particular coherent diffraction. Two independent detector systems will be integrated into the diffractometer. The first, a 2D area detector (initially a PI-MTE) will enable the study of coherent diffraction. Secondly, a polarisation analyser stage will measure the polarisation state of the diffracted x-ray beam. The diffractometer is to be fully integrated into the TPS working environment and as such will be equipped with control and vacuum equipment that can be maintained and managed by TPS staff.

The conceptual design of the TACoDE endstation has been made with consideration to the existing RASOR diffractometer (Diamond Light Source)[1] (see appendices), although RASOR was not designed specifically for coherent diffraction, we aim to preserve positive aspects of RASOR while avoiding any negative aspects.

2.1 Required Properties

The following properties are highlighted as necessary for the proposed research to be undertaken and are therefore non-negotiable.

- Direct provision for cabling and water cooling for future area detectors through vacuum ports on a rotating delta circle.

- A cryostat length of no more than 345mm (to achieve stability requirements and minimise thermal expansion), and sufficient space for a cryostat of diameter 60mm.

- Access through a removable (without mechanical assistance) flange on the front of the diffractometer.

- Motions as specified in section 2.11.
• Ports of conflat flange as specified in Tables 1 and 2 (detailed arrangement, port size, and orientation will be finalized in the kick-off meeting).

2.2 Beamline Characteristics of the TPS beamline 41A

The diffractometer will be commissioned and installed on beamline 41A. This diffractometer will be the second of three endstations on the beamline. The incident x-ray beam will be horizontal with a beamheight of 1047mm. There will be a beam that passes the diffractometer in a vacuum pipe above and to one side of the diffractometer. This bypass beam will bypass away from the ring (negative x), and as such is on the opposite side to the opening door. Any change in the overall size of the vacuum chamber needs to be specifically approved by NSSRC.

2.3 Outline

The following sections propose the general design of TACoDE. Companies are encouraged to suggest changes to the design to improve the functionality of ease construction or maintenance. Such changed must be approved by NSRRC in the design stage. NSRRC reserves the right to modify the conceptual design before the kick-off meeting held in one month after start of contract. Detailed design will be finalized in the kick-off meeting.

The endstation comprises of an in-vacuum (UHV) diffractometer based on six circle geometry\[2\](see appendices) with two principle rotations, delta (detector) and theta (sample). The diffractometer will have two detector systems; an area detector and a polarisation analyser. These will each be mounted on independent out-of-plane gamma rotations. The provision of gamma rotations removes the need for a chi rotation of the sample position, enabling a dramatic reduction in the size of the sample translations (sx, sy, sz), and in turn a reduction in the length of the cryostat from RASOR.

The majority of the back flange of the vacuum chamber will form the delta rotation with the theta rotation mounted upon this. This means that the delta and theta rotations are not independent and working in air environment, in order to maintain a fixed theta position when moving delta, theta must be driven in the opposite direction at an equal speed. The reasoning of a large delta rotation allows the cabling for the detectors
and polarisation stage to be routed directly out of ports and minimises invacuum cable management. It importantly allows water cooling through a port for the 2D detector. This functionality is essential for future-proofing the installation of area detectors in development, the requirements of which are as yet unknown.

In order to achieve a high reliability and lifespan, both the theta and delta rotation circles must run in air with double pumped vacuum feedthroughs.

2.4 Definitions and References

2.4.1 Co-ordinate System

\( x \) axis is a horizontal axis, perpendicular to the beam. The positive x axis points to the left when viewing the source.

\( y \) axis is vertical, with +ve \( y \) upwards.

\( z \) axis is coincident with and points away from the x-ray source. \( x \), \( y \), and \( z \) form a right handed co-ordinate system.

Pitch is a rotation about \( x \).

Roll is a rotation about \( z \).

Yaw is a rotation about \( y \).

Scattering Plane The scattering plane contains the incident and scattered beam. In this co-ordinate system it corresponds to the \( yz \) plane, perpendicular to the rotation axis of sample and detector arms.

Upstream Towards the synchrotron x-ray source (-ve \( z \)).

Downstream Away from the synchrotron x-ray source (+ve \( z \)).

Front Diffractometer face at positive \( x \).
Centre of Rotation (COR)  Single point corresponding to the intersection of the th and del (parallel and co-incident) and gam_{ccd} and gam_{pa} rotation axes.

Sphere of Confusion (SOC)  Minimum volume around COR enclosing all of the actual individual rotation processions.

2.4.2 Definitions

Range: The maximum range of position available to a motion which is protected at either end by limit switches and non binding end stops.

Resolution: Minimal incremental step size that can be achieved with <20% accuracy.

Repeatability: The range of deviations in output positions that occurs for the same input command position.

Accuracy: The maximum absolute positioning error over the full range of motion.

Backlash: The maximum difference in absolute position obtained by approaching the required position by any route.

Stability: The maximum change in absolute position with no change in input position over an extended time period (typically 24 hours).

2.5 Diffractometer Axes, Motions and Mnemonics

Required specifications for all of the diffractometer rotation axes and translations are given in Tables 3,6,4 in section 2.11
Figure 1: Schematic of the motions with mnemonics of diffractometer system. In-vacuum motions are shown in red and black, and table motions in grey. Dash-dot lines show rotation axes, and dotted lines indicate arc circles.
2.5.1 Motion hierarchy

This schematic shows the relative hierarchy of the motion, in terms of which motions are mounted on which. Motions in red indicate in-vacuum motions.

2.5.2 Principle diffractometer axis

\textbf{theta (th)} Rotation of the cryostat with sample around the $x$ axis. \( \text{th} = 0 \) when the sample surface is horizontal and upright. Positive is a right hand rotation around $x$.

\textbf{delta (del)} Rotation of the detector arm around the $x$ axis. \( \text{th} \) and \( \text{del} \) are coincident and parallel. Positive rotation corresponds to positive \( \text{th} \) rotation, and is a right hand rotation around $x$.

2.5.3 Sample translations

\textbf{sx} Translation of the cryostat mounted on the \( \text{th} \) rotation moving the cryostat parallel to the long axis of the cryostat. Translation acts along the $x$ axis. Positive corresponds to positive $x$. \( \text{sx} = 0 \) corresponds to the centre of the translation movement.

\textbf{sz} Translation of the cryostat mounted on the \( \text{th} \) rotation. Perpendicular to \( \text{sx} \) and translation acts along $z$ (beam) when \( \text{th} = 0 \). Positive corresponds to positive in $z$ when \( \text{th} = 0 \). \( \text{sz} = 0 \) corresponds to the centre of the translation movement.
sy Translation of the cryostat mounted on the th rotation. Perpendicular to sx and sz and translation acts along y (vertical) when th= 0. Positive corresponds to positive in y when th= 0. sy= 0 corresponds to the centre of the translation movement.

2.5.4 In-vacuum Gamma Rotations

gam CCD Out of scattering plane rotation of the 2D (CCD) detector. Rotation axis is within the scattering (yz) plane and through the COR. gam CCD = 0 corresponds to the direct beam incident on the centre of the detector with an appropriate del. Positive is a right hand rotation around y when CCD is viewing the direct beam.

gam PA Out of scattering plane rotation of the 2D (CCD) detector. Rotation axis is within the scattering (yz) plane and through the COR, and gam CCD = 0 corresponds to the direct beam incident on the centre of the detector with an appropriate del. Positive is a right hand rotation around y when the PA detector is viewing the direct beam.

gam CCD and gam PA are offset in del, such that the direct beam is incident on each detector at different del. The offset will be $\sim 30^\circ$.

2.5.5 In-vacuum Polarisation Analyser (PA)

eta Rotation of the PA around the scattered beam. Rotation axis is equivalent to z when gam PA = 0 and del is such that gam PA axis corresponds to y. eta= 0 when thp and ttp rotation axes are parallel to x. Positive is a right hand rotation around z when the PA in the direct beam

ttp Rotation of the detector arm on the polarisation stage. Rotation axis is parallel to x when eta = 0. ttp = 0 when the direct beam is incident on the detector. Positive direction a right hand rotation around x when eta = 0.

thp Rotation of the PA crystal stage. Rotation axis is always parallel and coincident to ttp rotation axis. Positive direction is as ttp is a right hand rotation around x when eta = 0.
py  Y translation of the PA crystal. Translation is perpendicular to \( \text{thp} \) axis and parallel to \( y \) when \( \eta = 0, \text{thp} = 0, \text{gam}_{pa} = 0, \) and \( \text{del} \) is such that PA is in the direct beam. \( py = 0 \) lies in the centre of the translation and corresponds to the rotation axis of \( \text{ttt} \). Positive is positive in \( y \) when \( \text{thp} = 0, \eta = 0, \text{gam}_{pa} = 0, \) and \( \text{del} \) is such that PA is in the direct beam.

pz  Z translation of the PA crystal. Translation is perpendicular to \( \text{thp} \) axis and parallel to \( z \) when \( \text{thp} = 0, \text{gam}_{pa} = 0, \) and \( \text{del} \) is such that PA is in the direct beam. \( pz = 0 \) lies in the centre of the translation and corresponds to the rotation axis of \( \text{ttt} \). Positive is positive in \( z \) with \( \text{thp} = 0, \eta = 0, \text{gam}_{pa} = 0 \) and \( \text{del} \) is such that PA is in the direct beam.

ds  Detector slits immediately in front of the polarisation analyser. Parallel to \( y \) when \( \text{gam}_{pa} = 0 \) and \( \text{del} \) is such that PA is in the direct beam. \( ds = 0 \) corresponds to the -ve \( y \) limit of the translation. Positive direction corresponds +ve \( y \).

2.5.6 Table Motions

alpha  Rotation of the chamber and diffractometer. Used to correct the yaw of the diffractometer. Rotation axis corresponds to \( y \) and should pass through the COR.

dx  Translation of the diffractometer system. Translation parallel to \( x \). Used to place the COR horizontally perpendicular to the beam onto the beam. \( dx = 0 \) is the centre of the translation, positive is in the direction of \( x \).

\( \text{leg}_1, \text{leg}_2, \text{leg}_3 \)  Adjustable legs providing vertical translation and levelling of the diffractometer system. Translation should be parallel to \( y \). Used to place the COR vertically on the beam. \( \text{leg}_1 = 0, \text{leg}_2 = 0, \text{leg}_3 = 0 \) corresponds the centre of each leg adjustment, positive is in the direction of \( y \).
Figure 2: General outline of the diffractometer, with the incident synchrotron beam entering from the left.
Figure 3: General outline of the rear of the diffractometer with the del1 and th rotation circles mounted on the rear flange. The incident beam enters from the right hand side.
Figure 4: View of the inside of the diffractometer showing mounting points and the two gamma stages mounted on the inside of the del circle.
2.6 Realisation of Diffractometer

2.6.1 Vacuum Chamber and Table

The diffractometer is based around a cylindrical stainless steel vacuum chamber of size 800mm diameter and 400mm depth. The chamber is supported by a table providing an alpha motion (±1°, and horizontal translation (±5 mm) perpendicular to the synchrotron x-ray beam (dx). Three legs provide a vertical translation (±5 mm) in addition to levelling the chamber.

The table provides a stable platform for the chamber positioning the centre of the chamber to a beamheight of 1047mm. In addition it should support all required vacuum components, including where necessary support for the proposed ion pump and gate valve. The pumps and valves are free issued, however the manufacturer will supply any additional necessary vacuum components (such as vacuum piping) to complete the vacuum assembly. Vendors are required to present the detailed design of table prior to the kick-off meeting, especially the performance of table stability and vibration. The table design should be approved by NSRRC in the kick-off meeting.

The front of the chamber provides access to the instrument, as well as supporting a loadlock (not part of tender) on the front flange. The front face of the instrument has been dished outward to allow a thinner wall thickness, and therefore less weight. The entire front flange should be hinged or equivalent to allow opening or removal and refitting without any lifting equipment. A differential pumping system with two viton seals is suggested as a suitable sealing method for this door.

2.6.2 del Rotation

The rear flange of the vacuum chamber accommodates the del circle. This is almost as large as the entire rear flange and upon which is mounted vacuum ports for detector and in-vacuum motor wiring and water cooling for the 2D area detector. This allows much smaller cable lengths and allows easy installation of a vacuum guard around water cooling pipes to the area detector. The significant mechanical problem will be the very large vacuum forces present on the rotation circle. With a radius of 300mm this gives a vacuum force of 30kN. To maintain a good vacuum within the chamber the rotation will have a double pumped seal. It is encouraged that manufacturers should aim to reduce the size of this del rotation where possible, while retaining feedthroughs for the detectors and the motors. DN16CF vacuum flanges are
Figure 5: Front of the vacuum chamber showing the domed access door. This should either be hinged or on a slide mechanism. The table provides $\alpha$, $dx$ and vertical motions through three legs, leg$_1$, leg$_2$ and leg$_3$. 
required on this flange for maintaining future cabling requirements. Sufficient ports are needed for full operation at delivery (including use of the PI-MTE area detector) and in addition a minimum of ten further DN16CF ports will be provided for future use. Details information of ports are shown in section 2.9.

The del rotation has been designed such that the rotating circle that the th rotation and feedthroughs are mounted upon is as close to the beam as possible, to minimise the cryostat length, which should not be more than 345mm. This rotation should be provided with an optical encoder (this can be mounted on the outside of the chamber).

2.6.3 th rotation

The sample, th, rotation is mounted on the del circle and provides a rotation for the cryostat. On the th rotation are mounted the sy, sz and sx sample translations. UHV edge welded bellows maintain vacuum to the cryostat mounted on the top of the translation stages. A DN63CF bellows is used to provide an internal rotation bore diameter of a minimum 60mm, required for the cryostat. As with the del rotation a double pumped feedthrough should be used to maintain UHV vacuum. The rotation circle should provide a mounting point within the vacuum chamber that rotates with th, with a maximum load of 5kg.

2.6.4 sx, sy, sz translations

The cryostat should be mounted on a three way translation stage. Each translation should have ±5mm travel. The conceptual design has been carefully designed to minimise the height of these translation stages. The bellows allowing this movement have an internal diameter of 66mm, minimising the vacuum force to 350N. This should allow a much smaller translation compared to RASOR. In addition the provision of a loadlock minimises the required motion of sx. The distance from the cryostat mounting flange to the COR is required to be no greater than 345mm.

2.6.5 Cryostat

A UHV liquid helium flow cryostat will be mounted on the sample translation stages. This is not included in this tender. The manufacturer will supply a
Figure 6: Rear flange of chamber, with the rotation circles. The large del 
circle is shown within which lie vacuum port flanges and in the centre the 
flange the th rotation, sx, sy, sz and cryostat.
Figure 7: th rotation on the del circle, with sx, sy, sz stages and the cryostat mounted on the th circle.
Figure 8: $sx, sy, sz$ stage with $th$ rotation behind, and cryostat mounted on the final translation stage.
'dummy' cryostat that will have the overall similar dimensions to the cryostat, but with no cooling. It will have a threaded M6 hole at the sample end along and coincident with the \text{th} rotation, such that it can be used for room temperature experiments. It can also be used for mounted alignment equipment for the purposes of factory and acceptance tests. The cryostat will be mounted to the sample translation stages maintaining vacuum using edge welded bellows.

The mounting of the cryostat is made using a ground metal-metal face to retain precise alignment. The cryostat will be manufactured by Janis and be based on their ST400 design, with the flange modified such that a metal mating face provides precise alignment. The cryostat should mounted such that it is easily removable (by TPS staff), and if deemed necessary an appropriate carriage should be provided to do this minimising the risk of damage.

The cryostat will require a minimum clearance of 60mm throughout the entire length. The length of the cryostat will not exceed 345mm, and the cryostat will be mounted using a custom flange no smaller than a DN63CF. This flange is expected to be vacuum sealed using either a viton seal or a helicoflex. The exact specifications of the flange will be agreed during the design phase.

2.6.6 gamma rotations

The TACoDE endstation will initially be equipped with 2 detector systems, a two dimensional detector, and a polarisation analyser stage. These will be mounted on two separate circles $\text{gam}_{ccd}$ and $\text{gam}_{pa}$, each providing $\pm 10^\circ$. The polarisation analyser will be mounted at a higher $\text{del}$ angle, and it is vital is that the detector system at higher $\text{del}$ can be completely moved out of the path of the incident beam when at high $\text{del}$ angle. Both the $\text{gam}_{ccd}$ and $\text{gam}_{pa}$ arcs must have a rotation axis coincident to the COR and perpendicular to the vector joining the COR and the centre of the relevant detector.

2.6.7 2D Detector

The endstation must provide a mount for the Princeton Instrument PI-MTE CCD detector. The front face of this detector should be no less than 200mm from the COR, and the detector should be mounted on the $\text{gam}_{ccd}$ arc. The detector requires water cooling. In order to eliminate vacuum-liquid joints, a
Figure 9: $\text{gam}_{\text{ccd}}$ and $\text{gam}_{\text{pa}}$ stages providing out of scattering plane rotations for the PA and area detector. The area detector requires cooling water, with the pipes visible. The CF flange braised on the pipes will be connected to flexible bellows providing a vacuum guard.
CF flange will be brazed on the cooling pipes, which will be modified to fit in the chamber. A vacuum guard comprising of flexible bellows will connect the cooling pipes to an external flange(s) on the del rotation. A second flange will be provided for the electrical connector from this and from the detectors on the polarisation analyser. It should be assumed that this detector will be replaced by future 2D detectors and as such provision should be made to enable this. This includes the provision of additional ports on the del circle as described in section 2.9, and the detector mount on the gam_\text{ccd} rotation must be sufficient to support 5kg at the detector position at any del angle without deviating from the required SOC requirements.

2.6.8 Polarisation Analyser (PA)

The polarisation analyser measures the polarisation state of the scattered beam through a secondary scattering process where the ttp of the scattering process is close to 90°. This second Bragg scattering process allows through only light that is \sigma polarised relative to the PA. As the PA is rotated around the scattered beam (eta) the linear polarisation state of the beam can be deduced. The Bragg scattering is provided by W-BC multilayer crystals (not part of tender) of which there must be provision to mount up to three simultaneously. These multilayers are circular of diameter 12.7mm and 5mm thick.

The PA will be mounted on the second gamma rotation. It functions in exactly the same way as the analyser within the RASOR diffractometer. This stage must be significantly small and is based on piezo motions available from PI-MICOS. It is essential that the full range of motions (ttp and eta) are available at all gam_{\text{pa}} values. The nearest part of the PA (including the aperture stage) should be no closer than 200mm from the COR.

The polarisation analyser is comprised of:

**Aperture stage (ds)**

Mounted immediately prior to the polarisation analyser, this is a single translation stage with a metal plate with letterbox apertures that can be translated in and out of the beam. The stage should have a range of $\sim$ 25mm. Portrayed by PI-MICOS PPS-20-26.
Figure 10: The Polarisation Analyser comprising of an aperture translation (far right), eta rotation (right), thp rotation (bottom) with py, pz and then multilayers mounted. The ttp rotation (top) with two detectors (photodiode not visible)
**eta rotation**

This is the main rotation of the PA, upon which the other rotation stages are mounted. The rotation axis is coincident with the COR, and corresponds to the direction of synchrotron x-ray beam at $\delta_1 = 0$ and $\gamma_{pa} = 0$. Required range $-135^\circ$ to $190^\circ$. Portrayed by PI-MICOS PR32.

**thp, py, pz**

The thp rotation circle is mounted on eta, with the rotation axis perpendicular to eta and within the scattering plane when eta= 0. Required range $-10^\circ$ to $100^\circ$. Portrayed by PI-MICOS PR32.

On top of the thp stage is two crossed translations. These allow the multilayers to be moved in and out of the beam (py - 12mm travel) and translate each of the three multilayers into the beam (pz - 25mm travel). These are portrayed by PI-MICOS PP22 (py) and PPS-20-26(pz). The centre of the multilayers should be positioned in the COR of the PA stage. The multilayers will be mounted on a removable carriage such that a different three multilayers can be exchanged.

**ttp rotation**

The ttp rotation supports the detectors on the PA stage. Mounts should be provided for a Burle channeltron 4869, and a IRD photodiode detector AXUV100. These detectors can be separated by an offset in ttp, and should be directed at the COR of the PA, and lie in the scattering plane of the PA. Both detectors should be mounted such that they can be easily replaced. The wiring should be through an in-vacuum bulkhead on the ttp rotation using SMA and MHV connectors.

### 2.7 Loadlock

The DN63CF flange in the middle of the door on the front of the chamber will be used for a loadlock system (not included in this tender). As such, the chamber and door must be designed such that a mass of 30kg can be bolted to this flange with no additional support required. This should also be taken into account when designing the opening of the door. The door must be able to be fully operated with the loadlock in place. Further details
of the proposed sample transfer loadlock can be provided on request. In additional four more DN100CF flanges (supplied with view ports) are required to facilitate sample transfer. These four flanges will be arranged in a square array and will be facing the COR, and be at an angle of 30° from the centre of the flange.

2.8 In-vacuum mounting points

At the base of the chamber on the vacuum side should be twelve individual M8 threaded mounting points. These will be used for mounting magnets and pinhole systems. These should be arranged in three squares (each with 4 mounts) with each set of 4 mounts arranged in a square array around a vacuum flange. One set should be aligned below the COR, and the other two sets around flanges either side.

All sets of mounts should be capable of supporting 30kg.

2.9 Ports on vacuum chamber

2.9.1 Main Chamber

The main chamber should be equipped with at least 17 ports. Specifically the following ports and their positions shown in Table 1 are required.

2.9.2 Delta rotation

In addition there will be at minimum 22 DN16CF of flanges on the del rotation stage, as shown in Table 2.

2.10 Alignment procedure

The purpose of the alignment procedure is firstly to ensure the coincidence of the rotation circles of th, del, gam_{ccf} and gam_{pd} thereby minimise the SOC to within 30µm, and secondly to place this point on the incident beampath. This should be done accurately. There should also be methods for checking and adjusting the alignment of eta ttp and thp circles. The alignment of the table adjustments can either be designed such that no realignment is
Table 1: Ports on main chamber

<table>
<thead>
<tr>
<th>Port Number</th>
<th>Use</th>
<th>Position</th>
<th>Size</th>
<th>Supplied Flange</th>
<th>Distance from COR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Incident beam port</td>
<td>horizontal at incident beam</td>
<td>DN63CF</td>
<td>blank</td>
<td>500 mm</td>
</tr>
<tr>
<td>2</td>
<td>Exit beam port</td>
<td>horizontal, 180° from incident beam</td>
<td>DN63CF</td>
<td>blank</td>
<td>500 mm</td>
</tr>
<tr>
<td>3</td>
<td>Ion Pump</td>
<td>30° below incident beam</td>
<td>DN160CF</td>
<td>Angled vacuum pipe</td>
<td>500 mm</td>
</tr>
<tr>
<td>4</td>
<td>Turbo Pump</td>
<td>30° below exit beam</td>
<td>DN160CF</td>
<td>N/A</td>
<td>500 mm</td>
</tr>
<tr>
<td>5 - 9</td>
<td>Camera and upgrades</td>
<td>5 on upper half of chamber</td>
<td>DN160CF</td>
<td>Viewports</td>
<td>500 mm</td>
</tr>
<tr>
<td>10 - 12</td>
<td>Magnet &amp; Pinhole</td>
<td>3 on bottom section of chamber</td>
<td>DN100CF</td>
<td>blanks</td>
<td>500 mm</td>
</tr>
<tr>
<td>13</td>
<td>Loadlock</td>
<td>Centre of door</td>
<td>DN63CF</td>
<td>blank</td>
<td>350 mm</td>
</tr>
<tr>
<td>14 - 17</td>
<td>Camera</td>
<td>4 on door and toward to COR, 30° from the centre of the flange</td>
<td>DN100CF</td>
<td>Viewports</td>
<td>345 mm</td>
</tr>
</tbody>
</table>
Table 2: Ports on delta rotation

<table>
<thead>
<tr>
<th>Port Number</th>
<th>Use</th>
<th>Size</th>
<th>Supplied flange</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Channeltron HV</td>
<td>DN16CF</td>
<td>SHV feedthrough</td>
</tr>
<tr>
<td>19</td>
<td>Channeltron signal</td>
<td>DN16CF</td>
<td>BNC or SMA, floating shield</td>
</tr>
<tr>
<td>20</td>
<td>Photodiode signal</td>
<td>DN16CF</td>
<td>BNC or SMA, floating shield</td>
</tr>
<tr>
<td>21</td>
<td>CCD signal</td>
<td>DN16CF</td>
<td>Multipin feedthrough, TBC</td>
</tr>
<tr>
<td>22</td>
<td>CCD water in</td>
<td>DN16CF</td>
<td>Vacuum guard water feedthrough</td>
</tr>
<tr>
<td>23</td>
<td>CCD water out</td>
<td>DN16CF</td>
<td>Vacuum guard water feedthrough</td>
</tr>
<tr>
<td>24</td>
<td>thp drive</td>
<td>DN16CF</td>
<td>As required</td>
</tr>
<tr>
<td>25</td>
<td>ttp drive</td>
<td>DN16CF</td>
<td>As required</td>
</tr>
<tr>
<td>26</td>
<td>pz drive</td>
<td>DN16CF</td>
<td>As required</td>
</tr>
<tr>
<td>27</td>
<td>py drive</td>
<td>DN16CF</td>
<td>As required</td>
</tr>
<tr>
<td>28</td>
<td>eta drive</td>
<td>DN16CF</td>
<td>As required</td>
</tr>
<tr>
<td>29</td>
<td>ds drive</td>
<td>DN16CF</td>
<td>As required</td>
</tr>
<tr>
<td>30 - 39</td>
<td>spare</td>
<td>DN16CF</td>
<td>blanks</td>
</tr>
</tbody>
</table>

necessary, or an alignment procedure is an infrequent event (such as removing the chamber from the table for transportation).

The diffractometer should be designed such that the circles maintain their required SOC for a minimum of 24 months. Thus, realignment of the th, del, gamccd and gampa axes should require no more frequently than every 24 months. This realignment can be undertaken by the diffractometer supplier engineers, however a quote for this service must be returned with the tender response.

The alignment of the polarisation analyser should be conducted separately to the th and del circles. Because the polarisation analyser system is removable, it needs to be easily realigned as a routine procedure. The alignment of the three polarisation analyser circles (eta, thp, and ttp) and translations (py, pz) can be conducted out of the vacuum chamber before mounting onto the del arm. Once aligned the polarisation analyser with a PA system sphere of confusion of less than 50µm should then be aligned such that the rotation axis of eta is coincident to that of del to within 50µm. In addition, these axes should be perpendicular to within 0.02°. Thus the sphere of confusion of the PA and that of the th, del, gamccd and gampa diffractometer axis are linked.

The entire alignment of the polarisation analyser should be thoroughly
documented. Any custom tools required for this process should be included in the supplied items. A list of any standard alignment tools required should be made clear at the design review.

The specifications in section 2.11 must be met under repeated vacuum cycling. It is recognised that baking the system may alter the alignment. The baking procedure of the system must be clearly documented, including any realignment necessary post-baking. Realignment should not be necessary upon vacuum cycling.

There should be a procedure for aligning a sample onto the COR. This must be done under vacuum, and may involve the use of a positioning cone that can be translated into the beam in order to determine the COR. This can be specified to be present on the cryostat and supplied free issue. The positioning of the sample should be within the SOC.

In addition the supplier is required to provide sufficient survey features to define the 3-D spatial location of the diffractometer. The preferred survey references are detailed below.

- Two survey monuments positioned at each end of the diffractometer system directly above the incident beam. From a plan view a line drawn between these two points should intersect the COR. The accuracy with which this can be achieved should be quoted in the tender return. Two additional survey monuments should be mounted on the rotation feedthrough defining the rotation axes independent of vacuum forces on the chamber. The monuments are for mounting a 3.5” Taylor Hobson Spherical Target. A theodolite and laser track will be used for this aspect of the alignment.

- A horizontal reference to mount an electronic level for pitch and roll alignment (can be two separate references).

An outline proposal of the survey features and the supplier’s standard alignment process is required with the tender return. Final details must be discussed and agreed with NSRRC at the design review.

Thorough documentation should be provided outlining the alignment procedure.
2.11 Required performance of key items

2.11.1 Diffractometer System

Magnetic Field  The magnetic field at the centre of the chamber must not exceed 5 gauss. This specification must be met with \( \theta \) and \( \delta \) driving simultaneously, or any other single motion driving. The total magnetic field generated by any single motor must be less than 2 gauss at the sample position.

Internal Clearances  There must be sufficient space between the cold finger of the cryostat and any other part of the diffractometer at all possible motor positions. There should be no part of the \( \delta \) arm closer than 200mm in the scattering plane and 100mm in the \( x \) direction to the sample.

Weight and Lifting  The diffractometer should have lifting points. If the system is to be routinely separated for transportation, each unit must have lifting points. It must be possible to move the system over short distances (10 s metres) complete. Both crane lifting points and forklift/airpad points should be provided for the purpose.

Performance of Rotation axes and translation stages  Tables 3, 4 and 6 state the required parameters that the rotation and translation stages must meet.
Table 3: Load capacity and physical dimensions of the diffractometer. SOC = diameter of the sphere of confusion, COR = center of rotation.

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOC, th, del, $\gamma_{ccd}$ and $\gamma_{pa}$ rotations</td>
<td>$\leq 30 \mu m$</td>
</tr>
<tr>
<td>SOC, th, del, $\gamma_{ccd}$ $\gamma_{pa}$, and alpha rotation</td>
<td>$\leq 30 \mu m$</td>
</tr>
<tr>
<td>Polarisation Analyser SOC (eta, thp, ttp)</td>
<td>$\leq 30 \mu m$</td>
</tr>
<tr>
<td>Coincidence of th and eta rotation axes</td>
<td>$\leq 50 \mu m$</td>
</tr>
<tr>
<td>SOC, th and alpha rotations</td>
<td>$\leq 500 \mu m$</td>
</tr>
<tr>
<td>Positioning accuracy of diffractometer COR by table (x and z)</td>
<td>$\leq 20 \mu m$</td>
</tr>
<tr>
<td>Horizontal accuracy of diffractometer x and z axis</td>
<td>$\leq 0.05^\circ$</td>
</tr>
<tr>
<td>Load capacity on detector arm for load 300mm from the rotation axis (with guaranteed SOC)</td>
<td>$\geq 5$ kg</td>
</tr>
<tr>
<td>Load capacity, th arm at sample position (for guaranteed SOC)</td>
<td>$\geq 100$ g</td>
</tr>
<tr>
<td>Load capacity, sample environment holes on th-rotation (with guaranteed SOC of sample)</td>
<td>$\geq 5$ kg</td>
</tr>
<tr>
<td>Load capacity, detector position on PA</td>
<td>$\geq 200$ g</td>
</tr>
<tr>
<td>Beam height</td>
<td>1047 mm</td>
</tr>
</tbody>
</table>
Table 4: Requirements for parallelism and orthogonality.

<table>
<thead>
<tr>
<th>Axes</th>
<th>Deviation from parallelism/orthogonality</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{del} \parallel \theta$</td>
<td>$\leq 0.002^\circ$</td>
</tr>
<tr>
<td>$\text{th} \perp \text{gam}_{\text{ccd}}$</td>
<td>$\leq 0.02^\circ$</td>
</tr>
<tr>
<td>$\text{th} \perp \text{gam}_{\text{pa}}$</td>
<td>$\leq 0.02^\circ$</td>
</tr>
<tr>
<td>$\text{del} \perp \text{eta}$</td>
<td>$\leq 0.02^\circ$</td>
</tr>
<tr>
<td>$\text{eta} \perp (\text{ttp} \parallel \text{thp})$</td>
<td>$\leq 0.02^\circ$</td>
</tr>
<tr>
<td>$\text{thp} \perp \text{py} \perp \text{pz}$</td>
<td>$\leq 0.1^\circ$</td>
</tr>
<tr>
<td>$\text{del} \perp \text{ds}$</td>
<td>$\leq 0.1^\circ$</td>
</tr>
<tr>
<td>$\text{sx} \parallel \theta$</td>
<td>$\leq 0.1^\circ$</td>
</tr>
<tr>
<td>$\text{sx} \perp \text{sy} \perp \text{sz}$</td>
<td>$\leq 0.1^\circ$</td>
</tr>
<tr>
<td>$\text{del} \parallel \text{dx} \perp \alpha$</td>
<td>$\leq 0.1^\circ$</td>
</tr>
</tbody>
</table>

Table 5: Vacuum requirements for the entire system.

| Leak rate | $< 10^{-9}\text{mbar.litre.sec}^{-1}$ |
| Base pressure | $< 5 \times 10^{-9}\text{mbar}$ |
Table 6: Range, positioning resolution (Resol.), reproducibility (Repr.) and full range accuracy (Accur.) of the diffractometer motions, excluding the slits and mirror translations. The motor drives should be capable of running at the speed specified.

<table>
<thead>
<tr>
<th>Motion</th>
<th>Environment</th>
<th>Mnemonic</th>
<th>Range</th>
<th>Resol.</th>
<th>Repr.</th>
<th>Accur.</th>
<th>Speed</th>
<th>Encoder</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta$ rotation</td>
<td>air</td>
<td>th</td>
<td>$-100^\circ +190^\circ$</td>
<td>0.002$^\circ$</td>
<td>0.01$^\circ$</td>
<td>0.05$^\circ$</td>
<td>2$^\circ$/s</td>
<td>Yes</td>
</tr>
<tr>
<td>$\delta$ rotation</td>
<td>air</td>
<td>del</td>
<td>$-45^\circ +190^\circ$</td>
<td>0.002$^\circ$</td>
<td>0.01$^\circ$</td>
<td>0.05$^\circ$</td>
<td>2$^\circ$/s</td>
<td>Yes</td>
</tr>
<tr>
<td>$\gamma_{ccd}$ arc</td>
<td>in-vacuum</td>
<td>gam$_{ccd}$</td>
<td>$-10^\circ +10^\circ$</td>
<td>0.01$^\circ$</td>
<td>0.05$^\circ$</td>
<td>0.1$^\circ$</td>
<td>1$^\circ$/s</td>
<td>Yes</td>
</tr>
<tr>
<td>$\gamma_{pa}$ arc</td>
<td>in-vacuum</td>
<td>gam$_{pa}$</td>
<td>$-10^\circ +10^\circ$</td>
<td>0.01$^\circ$</td>
<td>0.05$^\circ$</td>
<td>0.1$^\circ$</td>
<td>1$^\circ$/s</td>
<td>Yes</td>
</tr>
<tr>
<td>sample translation</td>
<td>air</td>
<td>sx</td>
<td>$\pm$5mm</td>
<td>0.0005mm</td>
<td>0.005mm</td>
<td>0.02 mm</td>
<td>0.5 mm/s</td>
<td>Yes</td>
</tr>
<tr>
<td>sample translation</td>
<td>air</td>
<td>sy</td>
<td>$\pm$5mm</td>
<td>0.0005mm</td>
<td>0.005mm</td>
<td>0.02 mm</td>
<td>0.5 mm/s</td>
<td>Yes</td>
</tr>
<tr>
<td>sample translation</td>
<td>air</td>
<td>sz</td>
<td>$\pm$5mm</td>
<td>0.0005mm</td>
<td>0.005mm</td>
<td>0.02 mm</td>
<td>0.5 mm/s</td>
<td>Yes</td>
</tr>
<tr>
<td>$\eta$ rotation</td>
<td>in-vacuum</td>
<td>eta</td>
<td>$-135^\circ +190^\circ$</td>
<td>0.01$^\circ$</td>
<td>0.05$^\circ$</td>
<td>0.1$^\circ$</td>
<td>2$^\circ$/s</td>
<td>Yes</td>
</tr>
<tr>
<td>detector rotation</td>
<td>in-vacuum</td>
<td>ttp</td>
<td>$-45^\circ +190^\circ$*</td>
<td>0.01$^\circ$</td>
<td>0.05$^\circ$</td>
<td>0.1$^\circ$</td>
<td>2$^\circ$/s</td>
<td>Yes</td>
</tr>
<tr>
<td>PA crystal rotation</td>
<td>in-vacuum</td>
<td>thp</td>
<td>$-10^\circ +100^\circ$</td>
<td>0.01$^\circ$</td>
<td>0.1$^\circ$</td>
<td>0.05$^\circ$</td>
<td>2$^\circ$/s</td>
<td>Yes</td>
</tr>
<tr>
<td>PA translation</td>
<td>in-vacuum</td>
<td>pz</td>
<td>$\pm$13mm</td>
<td>0.005mm</td>
<td>0.05mm</td>
<td>0.1mm</td>
<td>1mm/s</td>
<td>Yes</td>
</tr>
<tr>
<td>PA translation</td>
<td>in-vacuum</td>
<td>py</td>
<td>$\pm$5mm</td>
<td>0.005mm</td>
<td>0.05mm</td>
<td>0.1mm</td>
<td>1mm/s</td>
<td>Yes</td>
</tr>
<tr>
<td>det. slit</td>
<td>in-vacuum</td>
<td>ds</td>
<td>$\pm$13mm</td>
<td>0.0005mm</td>
<td>0.001mm</td>
<td>0.02mm</td>
<td>1mm/s</td>
<td>Yes</td>
</tr>
<tr>
<td>Diffo rotation</td>
<td>air (Table)</td>
<td>alpha</td>
<td>$\pm1^\circ$</td>
<td>0.02$^\circ$</td>
<td>0.01$^\circ$</td>
<td>0.05$^\circ$</td>
<td>0.1$^\circ$/s</td>
<td>Yes</td>
</tr>
<tr>
<td>Diffo translation</td>
<td>air (Table)</td>
<td>dx</td>
<td>$\pm$5mm</td>
<td>0.0005mm</td>
<td>0.005mm</td>
<td>0.02mm</td>
<td>0.5$^\circ$/s</td>
<td>Yes</td>
</tr>
<tr>
<td>Diffo height</td>
<td>air (Table)</td>
<td>leg$_1$,leg$_2$,leg$_3$</td>
<td>$\pm$5mm</td>
<td>0.0005mm</td>
<td>0.005mm</td>
<td>0.02mm</td>
<td>0.5$^\circ$/s</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* The photodiode detector on the ttp arm must be able to look at the beam ‘forwards’ when del=0 and ttp=0, and ‘backwards’ when del=180 and ttp=180. This is necessary for alignment purposes.
3 General Mechanical Specifications

3.1 Fasteners and Fittings

All equipment should use austenitic stainless steel ISO metric hexagonal fasteners (BS EN ISO 4017), austenitic stainless steel ISO metric nuts (BS EN ISO 4032), and austenitic stainless steel ISO metric washers (BS EN ISO 7089).

Fasteners and nuts should conform to the materials and strength grade A4-70 and be identified as such as defined in EN ISO 3506 (parts 1 and 2). All in-vacuum threaded fasteners located in blind holes must have a central, coaxial vent hole.

The supplier will be required to supply spare fasteners for the diffractometer system, the quantities are to be agreed with NSRRC.

Unless otherwise specified by NSRRC, flanges must be in accordance with the CF standard. The layout drawings and port list (section 2.9 provided in this tender document indicate a number, size and location of flanges.

3.2 Mountings and Stands

All steel equipment must be painted in a colour to be agreed during the design phase.
4 Electrical System, Motor and Controls

All motor drive amplifiers, and piezo controllers required to operate the diffractometer system are excluded from the scope of the tender. However motors, limit switches etc. must be compatible for integration into guest beamline systems. All cables should be terminated in a patch panel mounted on the system, with termination’s described in section 4.4. Control software is excluded from the tender. It will be necessary however for the supplier to be able to demonstrate, and for testing, the operation of the diffractometer, by controlling all motions, and at minimum any two motors simultaneously. This is necessary before delivery for the factory site acceptance tests, and after delivery for site testing by the supplier.

4.1 Motors

The motions will be driven through a combination of stepper motors and piezo stages. Information regarding the proposed motors for each driven axis shall be submitted to NSRRC for approval. NSRRC reserve the right to free issue motors to the supplier or approved sub-contractor in order to ensure conformity with beamlines 41A.

Motors for use inside the vacuum chamber should be UHV rated, and excluding piezo motors, should include the facility for temperature monitoring.

4.2 Limit Switches

Each actuated drive shall include two limit switches to define the two extreme positions of each motion. One of these switches should be a precision home switch. Limit switches shall have NC (normally closed) contacts.

4.3 Encoders

All motion stages should be fitted with encoders. If the use of encoders is not possible this must be made clear in the tender return. All piezo motors, th, del, gam\textsubscript{pa} and gam\textsubscript{cod} must be fitted with encoders without exception.
4.4 Cabling

All non-vacuum cable and wiring must be LSOHFR (Low Smoke, Zero Halogen, Fire Retardant) unless specifically agreed otherwise, complying with IEC 60754-1 and IEC 60332. The oxygen index must be higher than 28 and acid gas emission less than 4% for the outer sheath. PVC compound must not be used. Wire and cabling must meet the current requirements of the IEE Regulations. Where movement is required, cable must be highly flexible, having minimal effect on mechanical performance, but offering suitable mechanical protection.

In vacuum cabling should be UHV compatible, and it is anticipated will be routed via a feedthrough mounted on the delrotation stage.

All the motor, limit switch and encoder cabling should be terminated in a bracket mounted socket shell. Stepper motors cables are to be terminated to EMC shielded ringlock style connectors with pins. Limit switches, and cabling for temperature monitoring of motors should be terminated with ringlock style EMC connectors with pins.

All encoders and piezo motions should be terminated with appropriate EMC shielded connectors (preferably ringlock style) with pins.

In addition, in-vacuum cabling for the channeltron and photodiode detectors should be provided. This should be kept as separate as reasonably possible from motor cabling when within the vacuum chamber and be terminated on a separate vacuum port to the motor cables. No external cabling is required for the detectors. The channeltron requires a HV co-axial cable rated to 3kV, and a separate shielded signal cable. The shielding for the channeltron signal cable should be isolated at all places and terminated at a floating electrical feedthrough (either SMA or BNC). The Photodiode requires a co-axial signal cable. This coaxial should be further shielded by a metallic mesh which should be grounded to the feedthrough and maybe also grounded elsewhere. The coaxial shield of photodiode cable should be connected to a floating co-axial electrical feedthrough, and remained isolated elsewhere. The detector end of the signal cable for the photodiode should be terminated on an IRD AXUV100CS socket.

4.5 Electrical Drawings

Electrical drawings must be provided in AutoCAD and Solidworks format and in pdf format. Full maintenance information must be provided, sufficient
to locate faults down to individual electronic component level, including but not limited to:

1. System block diagram and general assembly drawings.

2. Sub-assembly drawings including component layout and electrical schematics.

3. Setting up, calibration or configuration instructions.
5 Vacuum

5.1 General
The leak rate of the total system should be $< 10^{-9}$ mbar.litre.sec$^{-1}$, and suitable pumps specified to achieve a base pressure of the system of $< 5 \times 10^{-9}$ mbar without an x-ray beam. All pumps, gauges and controllers will be free issued by NSRRC. Pressure measurement will be by Pirani and Inverted Magnetron gauges.

5.2 Vacuum Equipment
The supplier must confirm that they possess equipment that is suitable to carry out leak testing, and acceptance tests for UHV items. This includes all stainless steel blanking flanges and suitable adaptors and pipe fittings to connect the test items to the leak detector. All blanking flanges, viewports, gaskets, fasteners and washers are to be provided by the supplier. NSRRC will free-issue to the supplier all ultra high vacuum pumps and gauges and associated controllers. It is anticipated that the vacuum will provided by a combination of ion and turbomolecular pumps with suitable roughing and backing pumps. NSRRC have a preference for Edwards turbo pumps and Gamma ion pumps. For this instrument we wish to minimise vibrations and therefore we suggest the use of magnetically levitated turbomolecular pumps. The design of the diffractometer system must be such that no custom modification to any vacuum equipment is required.

The details of items required (such as pumps gauges etc.) and the expected dates when they shall be required by the supplier shall be agreed during the design phase of the contract. If it is agreed between the manufacturer and NSRRC, the manufacturer can use their own vacuum equipment for the purpose of the factory acceptance tests, with the use of NSRRC equipment for site acceptance tests and thereafter.

5.3 Materials for UHV use
This list is not exhaustive. Some of the materials listed here may not be suitable for other reasons, e.g. magnetic permeability, temperature limitations, radiation resistance, etc. If materials other than those listed here are to be used then written permission is required from NSRRC.
Vessels:
Stainless steels - AISI 304L, 304L+N, 316L, 316L+N, 321, 347
Inconel 600, 625, 718, 750
Mumetal, Monel metal
Copper, OFHC and OFS grades
Titanium, Beryllium
Aluminium and alloys 5086, A-6061-T6, A-6063-T6, ISO AlMgSi6060, VAW 19/06 LWV Glass, high density Alumina, Beryllia

Flanges:
Hot forged ESR grade stainless steel type 304L, 304L+N or 316L or 316L+N.
For knife edges, a Brinell hardness of 160-200 is required.

Interior:
Most metals except Cadmium, Caesium, Mercury, Potassium, Magnesium, Sodium, Lead, Selenium, Strontium, Zinc.
Most alloys except those containing the above in such quantities or chemical state that they can segregate to the free surface.
Most high density ceramics.
PTFE, Mica

5.4 Machining and Fabrication

All machining work is to be carefully controlled to ensure that no foreign matter is embedded in the surface of the material.

The use of abrasive wheels or cloths (which can leave foreign matter embedded in the UHV surfaces), wire brushes, files, harsh abrasives, sand, shot or dry bead blasting, polishing pastes and the like is prohibited under normal circumstances and without the prior permission of the NSRRC.

Scale removal, etc., shall be by careful hand brushing with a stainless steel brush. Other surface finishing techniques which are permitted include slurry blasting with alumina or glass beads in a water jet; gentle hand use of a dry fine stone or a fine stone lubricated with isopropyl alcohol or ethanol; hand polishing using fine mesh alumina in an isopropyl alcohol or ethanol carrier on a lint free cloth and hand polishing with ScotchBrite™ (Alumina loaded, Grade A).
All mechanical cold working operations must exclude the use of heavy organic lubricants since these can be retained to some extent in the surface after the process.

**Welding** All parts to be welded must be thoroughly cleaned (degreased) to ensure UHV leak-tight welds. Prior to and during welding the cleaned surfaces must never be in contact with oily or greasy objects (including bare hands). All welding will be to BS7475, Part 2 or equivalent. Conventional welding will be by the TIG process although electron beam welding, plasma welding and laser welding may be used as appropriate and by agreement with the NSRRC. To prevent undue oxidation all vacuum sealing welds are to be backed by an inert gas purge. Where vacuum sealing welds are made externally there should be full penetration leaving a smooth surface inside, without any subsequent dressing operation.

**Brazing** This joining technique may be considered for copper to stainless steel joint or for copper alloy cooling tubes. All parts to be brazed must be thoroughly cleaned as outlined below. The quality assurance requirements as outlined in the main tender document must be met (including the production of a brazing plans, which may be part of the associated welding plan).

If at any stage of manufacture a weld or braze is found to be faulty, no rectification is to be done without prior approval from the NSRRC. The use of dye-penetrant is strictly forbidden at any stage of manufacture.

### 5.5 Marking and Labelling

At no time should any surface which is to be exposed to vacuum or immersed in vacuum (e.g. during a bake operation) be marked out, identified or the like except by scribing with a clean, dry sharp point or a vibrating engraver. Vacuum surfaces should only be marked if it is essential so to do. The use of dyes, marker pens, paints, etc. is to be avoided. It is good practice not to use these on external surfaces because of possible cross-contamination in subsequent cleaning operations. Similarly, it is possible to temporarily block porosity in material with such substances.

Labels for identification purposes should be tied to components or, in the case of small components, fixed to packing bags. Self adhesive labels, tapes, etc. if essential, may only be fixed to non-vacuum surfaces of components and
care should be taken to ensure that the adhesive used is soluble in acetone. QA barcode tracking labels should be laser engraved at the position identified on the appropriate drawings. Where this is impractical, these should take the form of a metal tag securely wired to the fixing point identified on the appropriate drawings.

5.6 Handling and Packing

Once components have completed the initial rough cleaning care should be taken that vacuum surfaces are never touched by bare skin. Gloves should always be used when handling components. Care should be taken in selecting such gloves. Polyethylene or natural vinyl is to be preferred. Coloured gloves should be tested to ensure that the dyes do not leach out when exposed to the solvents used. Gloves with talcum powder, chalk or other powders inside should be avoided since the powder can migrate into components. A good solution is to use lint-free fabric gloves inside polyethylene gloves.

Once components have started the cleaning process they should complete the cycle without a break. If it is unavoidable that a delay occurs between stages, then care must be exercised that the component is thoroughly dry before storage, and all seal faces and ports must be covered. There must never be a break between any chemical cleaning stage and a subsequent water washing stage.

After the component has been cleaned and is completely dry, it must be packed carefully to ensure that it remains clean and free from damage. Protect all seal faces and/or knife edges with clean used metal gaskets where possible; cover all ports with strong clean new aluminium foil and plastic covers. Small items should be wrapped in clean aluminium foil and sealed in a polyethylene bag, under dry nitrogen if possible.

5.7 Bakeout

It should be possible to bake the entire system up to 120°C. Evidence of suitable vacuum conditioning of the vacuum chamber will be required. The diffractometer system should be supplied with a bake-out suitable system, with supporting documentation capable of baking the entire vacuum system to 120°C. This should be possible without the removal of integrated components, i.e. external motors.
5.8 UHV Cleaning

5.8.1 Health and Safety

Many of the chemical agents and processes described in this document are subject to control or regulation under various parts of Health and Safety Legislation or Regulations. Any persons or Companies implementing all or any part of this Specification must satisfy themselves that they are conversant with and are adequately implementing any such Legislation or Regulations. They must ensure that they and their staff are fully conversant with all safety documentation issued by the suppliers of any such chemical agents or any equipment using such chemical agents and are fully conversant with the requisite safety precautions and personal protective equipment required. NSRRC cannot be held responsible for any consequences of the use of any chemical agent or process called in this document except where such use is under their direct control.

5.8.2 Comments on this Specification

Three overriding criteria have been applied in drawing up this cleaning specification.

The first is the considerable body of experience which synchrotron laboratories worldwide have accumulated regarding the cleanliness required for vacuum vessels particularly for the stringent requirements of Synchrotron Light Sources. The second is the applicable parts of Environmental Protection Legislation. In recent years this legislation has greatly restricted the types of chemical solvents which are permitted for metal cleaning purposes. It has also greatly increased the precautions to be taken in working with many permitted solvents.

The third is that there is at present some variation in what is permitted in some countries and not in others.

The overall effect is that this specification is rather complex and demands careful reading to determine which parts are applicable in any given situation.

5.8.3 General Procedures

**Inspection**  All components which are received for cleaning must be examined for damage before starting any operations. Particular attention should be paid to knife edges and other sealing faces to ensure that there are no
scratches, pits or other defects which could cause vacuum leaks. This should be repeated after each phase of cleaning.

Components should be carefully inspected so that any areas which might form potential contamination traps, e.g. blind holes, re-entrant volumes, crevices or cracks, are identified so that particular attention can be paid to ensuring that they are satisfactorily cleaned out.

**Mechanical Operations on Vacuum Surfaces** Abrasive techniques to clean or to attempt to improve the appearance of the surfaces of vacuum components must be kept to an absolute minimum and are preferably avoided. The use of grinding wheels, wire brushes, files, harsh abrasives, sand, shot or dry bead blasting, polishing pastes and the like is prohibited under normal circumstances and without the prior permission of NSRRC.

Permitted techniques are slurry blasting with alumina or glass beads in a water jet; gentle hand use of a dry fine stone or a fine stone lubricated with isopropyl alcohol or ethanol; hand polishing using fine mesh alumina in an isopropyl alcohol or ethanol carrier on a lint free cloth; hand polishing with ScotchBrite™ (Alumina loaded, Grade A).

If any such surface finish technique is employed, care must be taken that any powder or other residues are removed by copious washing in hot water.

Any other operations may be carried out only with the prior written permission by NSRRC.

**Use of Acids** Acid treatment of any sort is normally prohibited and may only be carried out with the specific prior agreement of the NSRRC. Most acid treatments are for cosmetic purposes only and may result in degradation of vacuum performance.

Components must not be pickled in acid baths.

If in exceptional circumstances acids are permitted, then exposure of the component must be kept to a minimum and must be followed by copious washing in hot demineralised water.

**Treatment of Weld Burn** One particular use of acid pastes is in the removal of weld burns. In general such burns do not affect vacuum performance and are best left alone. Any scaling must be removed using the techniques of Section 5.8.3 above.
If it is desired to remove burns, then slurry blasting with alumina in water or hand burnishing with alumina powder is a satisfactory alternative. Heavy abrading, grinding or wire brushing is prohibited. Hand finishing with ScotchBrite™ or a dry stone is permissible.

5.8.4 Standard Cleaning Procedure for Stainless Steel Components

**Preclean**  Remove all debris such as swarf by physical means such as blowing out with a high pressure air line, observing normal safety precautions. Remove gross contamination by washing out, swabbing or rinsing with any general purpose solvent. Scrubbing, wire brushing, grinding, filing or other mechanically abrasive methods may not be used.

**Wash**  Wash in a high pressure hot water (approx. 80°C) jet, using a simple mild alkaline detergent. Switch off detergent and continue to rinse thoroughly with water until all visible traces of detergent have been eliminated. If necessary, remove any scaling or deposited surface films by stripping with alumina or glass beads in a water jet in a slurry blaster. Wash down with a high pressure hot (approx. 80°C) water jet, with no detergent, ensuring that any residual beads are washed away. Pay particular attention to any trapped areas or crevices. Dry using an air blower with clean dry air, hot if possible.

**Chemical Clean**  Immerse completely in an ultrasonically agitated bath of clean hot stabilised trichloroethylene (Triklone N™) for at least 15 minutes, or until the item has reached the temperature of the bath, whichever is longer. Vapour wash in trichloroethylene vapour for at least 15 minutes, or until the item has reached the temperature of the hot vapour, whichever is longer. Ensure that all solvent residues have been drained off, paying particular attention to any trapped areas, blind holes etc. Wash down with a high pressure hot (approx. 80°C) water jet, using clean demineralised water. Detergent must not be used at this stage. Immerse in a bath of hot (60°C) alkaline degreaser (P3 Almeco™P36 or T5161) with ultrasonic agitation for 5 min. After removal from the bath carry out the next step of the procedure immediately. Wash down with a high pressure hot (approx. 80°C) water jet, using clean demineralised water. Detergent must not be used at this stage. Ensure that any particulate deposits from the alkaline bath are washed away.
Dry in an air oven at approx 100°C or with an air blower using clean, dry, hot air.

**Finishing** Allow to cool in a dry, dust free area. Inspect the item for signs of contamination, faulty cleaning or damage. Pack and protect as outlined in section 6.

### 5.8.5 Alternative Cleaning Processes for Stainless Steel

It is recognised the many manufacturers will be unable to comply in detail with section 5.8.4 of this specification. The following alternative chemicals will be deemed acceptable, but must be agreed in advance in writing with NSRRC. Other procedures may also be acceptable and the use of these must also be agreed in advance between the manufacturer and NSRRC.

**Replacement solvents for section 5.8.4**  
- Trichloroethane, where local regulations permit its use
- Perchloroethylene, where local regulations permit its use
- Isopropyl Alcohol
- Ethyl Alcohol
- Acetone

### 5.8.6 Cleaning Procedures for Copper Components

In general, copper is cleaned in the same manner as stainless steel. In exceptional circumstances a light chromic acid or citric acid etch may be carried out with the prior written agreement of NSRRC, and section 5.8.3 must be observed.

### 5.8.7 Cleaning Procedures for Vacuum Bellows

**General** Great care has to be exercised when cleaning thin walled metal bellows, particularly those of edge-welded, nested construction. If any solvent residues are trapped between the convolutions, either inside or outside, these can result in corrosion which can rapidly cause leaks to develop. Similarly, if any particulates are deposited in the convolutions, mechanical puncturing can take place. Alkaline degreasing solutions are prone to particulate precipitation and therefore must not be used for bellows assemblies.
Procedure The bellows should be fixed in an extended position if possible. Remove any traces of visible, loose contamination with a jet of clean, dry air or nitrogen. Immerse in an ultrasonically agitated bath of isopropyl alcohol (IPA) or ethyl alcohol (ethanol). Vapour wash immediately in isopropyl alcohol or ethanol vapour. Thoroughly dry the bellows inside and out using a jet of clean, dry, particulate free air or nitrogen. Rinse in acetone or ethyl alcohol. Thoroughly dry the bellows inside and out using a jet of clean, dry, particulate free air or nitrogen. Dry in an air oven at 100°C for at least 1 hour. Bake, preferably by total immersion in a vacuum oven, for 24 hours at 250°C. Seal under dry nitrogen in a polyethylene bag.

5.8.8 Ceramics

Remove any surface contamination by wet slurry blasting with alumina powder, or by hand polishing with fine-mesh alumina powder in an acetone, ethanol or isopropyl alcohol carrier. Air bake at 1000°C for 24 hours. Wrap in aluminium foil and seal under dry nitrogen in a polyethylene bag.

5.8.9 Aluminium Components

General Aluminium may be cleaned by the process for stainless steel in Section 6 above, but care has to be taken. It should only be used for small components. Prolonged contact of aluminium with trichloroethylene may cause a reaction with gas generation. Very thorough washing with a jet of hot demineralised water is required after exposure of aluminium to trichloroethylene followed by very thorough drying.

CERN Procedure The CERN specification for LEP aluminium chambers is as follows and this process is the preferred treatment for large vessels. Spray with high pressure jets at 60°C with a 2% solution of Almeco 29™ (an alkaline detergent). Repeat with a 2% solution of Amkene D Forte™. Rinse thoroughly with a jet of hot demineralised water.
Dry with hot air at 80°C.

**Alternative Procedure**  Another procedure known to give good results and which is acceptable is as follows.
Immerse in Sodium Hydroxide (45 g.l$^{-1}$ of solution) at 45°C for 1 - 2 min.
Rinse in hot demineralised water.
Immerse in an acid bath containing Nitric acid (50% v/v) and Hydrofluoric acid (3% v/v).
Rinse in hot demineralised water.
Dry in warm air.

### 5.8.10 Assemblies and Sub-assemblies

Many assemblies and sub-assemblies will contain components for which, as individual items, more than one of the above cleaning procedures would be applicable. Wherever possible, individual components should be cleaned according to the appropriate procedure and assembly should then take place under clean conditions. Where this is not possible, the assembly must be cleaned according to the most delicate part, which will often be a bellows.
6 Packing and Delivery

6.1 Delivery

The diffractometer system should be delivered to Taiwan Photon Source, NSRRC, 101 Hsin-Ann Road, Hsinchu Science Park, Hsinchu 30076, Taiwan. This system should be delivered within the timescale outlined previously.

6.2 Packing

The items should be delivered robustly supported inside wooden crates. These must be capable of preventing damage or contamination during transit, and allow storage of the crated items for a period of two weeks in an indoor environment. The packing cases will not be returned. Packing cases must be suitable for lifting both with a forklift truck and a crane. The system should be delivered as fully assembled as possible.

The delivery address and ‘TACoDE PROJECT’ must be clearly displayed on the outside of all of the containers. In addition the following must be clearly displayed:

1. The weight of the loaded container
2. Support points for transport and listing

Each packing case must contain a copy of the packing list and customs invoice if applicable.

6.3 Shipped Condition

The vacuum chamber and any integrated components that can safely be shipped assembled should be sealed with blank flanges and shipped under vacuum. Any internal items not shipped within the vacuum chamber, following bakeout and completion of factory acceptance tests, shall be vented to clean dry nitrogen, grade 5.2 or better, wrapped in UHV grade aluminium foil and packed “double bagged” in a dry nitrogen atmosphere. The diffractometer system should be fully reassembled by the supplier at Taiwan Photon Source within 2 weeks of delivery. Details of the shipment procedures and associated equipment must be approved by NSRRC before any shipments are made.
7 Quality Assurance and Testing

7.1 Quality Assurance Testing
The supplier shall follow a quality assurance programme compliant with ISO-9001 for the design, manufacture and testing of all systems and equipment provided by them. The supplier must provide a quality assurance document for the supplied equipment, certifying that it conforms to the specification and the supplied engineering drawings, and containing all material certificates, the results of all inspections and tests and the procedures used.

7.2 Material Traceability
All material exposed to UHV must have material certificates. These should state the material specification, ladle analysis, room temperature mechanical properties and surface finishing process used. Explosion bonded material, if used, must be 100% ultrasonically tested to prove that the bond is complete over the entire material interface. All fasteners, washers, gaskets and other fittings must have a certificate of conformance to the agreed specifications.

7.3 Additional documents to be supplied
7.3.1 With the shipment of each assembly
  • All procurement documentation for materials and bought-in items.
  • Certificates of Conformance or Material Certificates as appropriate.
  • All test, inspection and acceptance test reports.
  • Final as-built drawings where any changes or concessions subsequent to the design review have been agreed in writing with NSRRC.

7.3.2 With the shipment of the final assembly
  • A complete set of as-built drawings in electronic (AutoCAD, Solidworks and pdf) format.
  • A complete set of quality control documentation in electronic format.
7.4 General arrangement for tests

The tests at the factory and on-site together must establish that all items of the manufactured equipment completely meet the performance requirements as described in this specification.

NSRRC reserves the right to require additional or more extensive tests to be conducted in the event of marginal design or performance.

The supplier must formulate acceptance test procedures for all systems and will provide the facility and instrumentation to perform all relevant tests to ensure compliance with this specification. The acceptance tests procedures must include, but not be limited to all of the testing procedures specifically outlined in this document, but also those necessary to prove compliance with this specification. These test procedures are subject to NSRRC review and acceptance. NSRRC or its representative reserve the right to witness all tests and will be the sole arbiter as to their being satisfactory. Review and acceptance by NSRRC does not release the supplier from its responsibility to correct errors, oversights and omissions to ensure conformance to the specifications in this document.

7.5 Factory acceptance tests

The diffractometer system must be fully assembled, aligned and tested at the suppliers site prior to shipping.

NSRRC and its authorised representatives must have access to the premises of the supplier for the purpose of inspection and witnessing of tests. NSRRC must be entitled to witness all tests defined in this specification and must be notified at least 21 working days in advance of any test date to allow the necessary travel arrangements to be made.

All tests must be undertaken with equipment and procedures approved by NSRRC. All tests must be properly recorded on test certificates and results submitted to NSRRC. NSRRC reserves the right to reject any material or component no completely fulfilling the conditions laid down in this specification. No component failing any specific test may be used in manufacture except with the written permission of NSRRC. In the event of any test failure, and subsequent rectification work, NSRRC reserves the right to repeat any previously unsuccessful tests.
7.5.1 Vacuum Tests

Visual  All vacuum-facing surfaces must be free from all visible defects such as pitting, scaling, cracks, indentations, weld spatter and loose material. Ensure that the sealing faces and knife-edge (if appropriate) are undamaged and free from radial scratches. All welds must be free from voids, blowholes, etc and inclusions.

Vacuum  Following cleaning, the supplier will carry out the following acceptance tests:

1. The supplier will demonstrate that the entire system has a total leak rate of $< 10^{-9}$ mbar.litre.sec$^{-1}$ at normal temperature.

2. The supplier will demonstrate that the internal base pressure of the system is $< 5 \times 10^{-9}$ mbar (nitrogen equivalent) at room temperature, using only the free issued vacuum pumps.

3. The supplier will provide a Residual Gas Analysis (RGA) spectrum of the system, which conforms to the following specifications.

   (a) The general contaminants (sum of the partial pressures of all peaks present in the RGA of amu equal to 39, 41-43, and 45 and above (excluding 66, 77 and any related to xenon and krypton) form $< 1\%$ of total pressure of system.

   (b) Perfluoropolyphenyletheres (sum of peaks at 69 and 77 amu) form $< 0.1\%$ of the total pressure of the system.

   (c) Chorinated species (Sum of peaks at 35 and 37 amu) form $< 0.1\%$ of the total pressure of the system.

7.5.2 Mechanical

Dimensional checks  Where geometrical tolerances are requested, these must also be measured and recorded. If any of the specified dimensions of the manufacturing drawings are not achieved, no rectification is to be made without prior approval of NSRRC. The accessibility for operational and maintenance purposes should also be checked.
Motion Tests  As well as comprehensive functional tests of all motorised / manual adjustments, the range, resolution and repeatability of all motor driven systems will be measured, together with the effectiveness of limit switches, home switches and physical stops (if applicable).

7.5.3 Electrical Acceptance Tests

The tests are to be defined by the supplier and agreed with by NSRRC at the design review and may include the following

1. Control and operation
2. Demonstration of axis accuracy, resolution and repeatability
3. Visual inspection
4. Accessibility assessment
5. External connections evaluation
6. Continuity and resistivity checks

7.6 Delivery Acceptance Tests

After delivery to the Taiwan Photon Source, and checking for damage occurred during transport, a repetition of all of the acceptance tests must be undertaken by the supplier in the presence of NSRRC. Equipment needed to undertake these tests must be provided my the supplier, but is returnable.

If additional work is required to pass these tests after delivery then this must be undertaken by the supplier. It will be a condition of final acceptance that these tests are undertaken and that the supplier must have provided to the satisfaction of NSRRC, full documentation as noted throughout this specification.
References


8 Appendices

On the following pages you will find the two papers referenced.