Statement of Work for the Nanoprobe Mirror System

Jörg Maser, Brian Stephenson, Robert Winarski

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1. Introduction

A horizontally focusing double mirror system is required as first optical component of the Nanoprobe beamline at sector 26 –ID of the Advanced Photon Source. The mirror system serves as high-heatload component, and provides horizontal focusing, power filtering, and higher harmonics rejection. The mirror system will be located 30 m from the x-ray source, and focus the undulator beam on a high-heatload aperture 40 m from the source.

This Statement of Work (SOW) describes the specifications and requirements for the Nanoprobe Mirror System. The mirror system consists of two water-cooled mirrors, a bending mechanism for the first mirror, a vacuum chamber that houses the mirrors, a support structure, positioners and encoders. The power requirements are listed in Appendix 1.

2. Technical Specifications

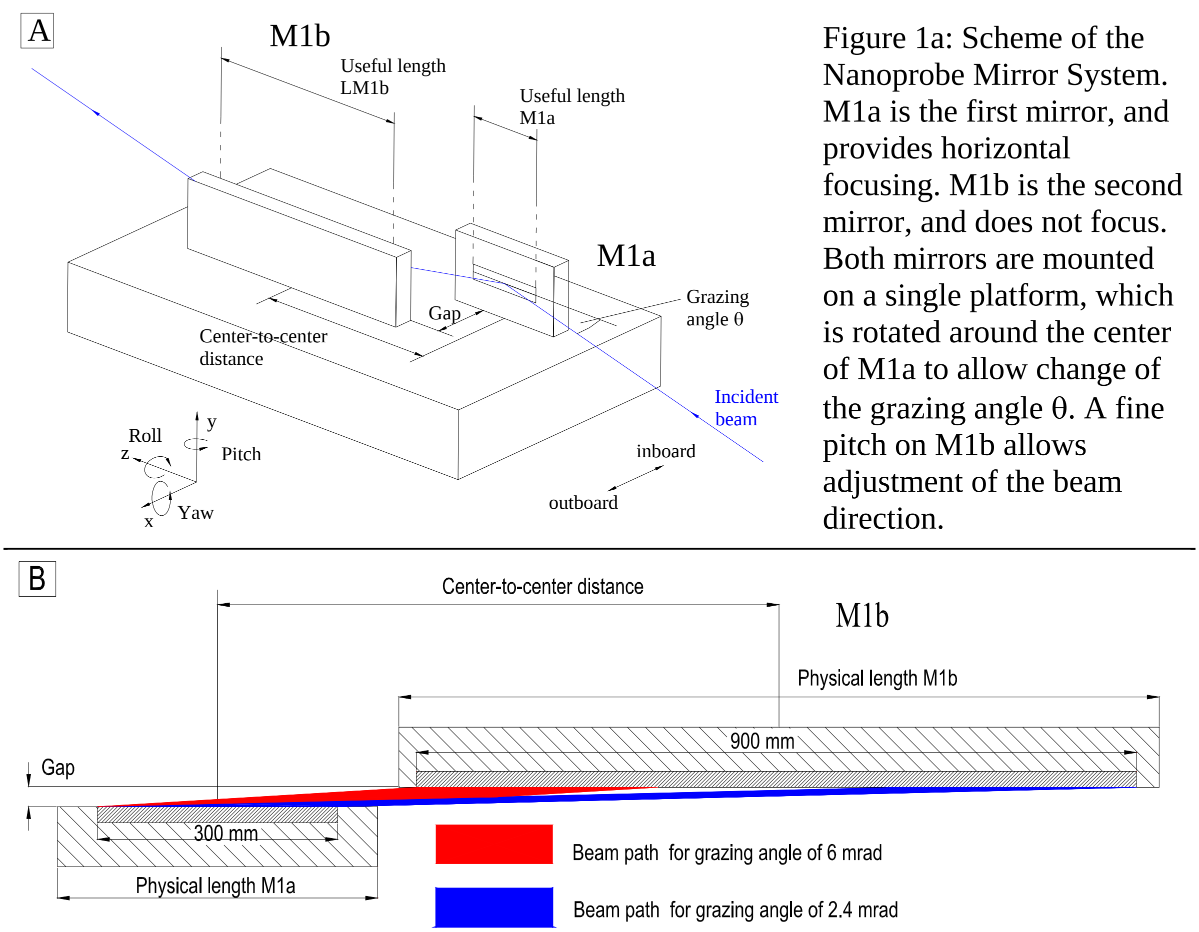

Figure 1a: Scheme of the Nanoprobe Mirror System. M1a is the first mirror, and provides horizontal focusing. M1b is the second mirror, and does not focus. Both mirrors are mounted on a single platform, which is rotated around the center of M1a to allow change of the grazing angle θ. A fine pitch on M1b allows adjustment of the beam direction.

Figure 1b: Top view of the mirror system. Anamorphic representation with a ratio of 10:1 for vertical:horizontal dimensions. A physical length of 400 mm of M1a and of 950 mm for M1b, respectively, is assumed for demonstration purposes only. These lengths can be chosen by the supplier.

2.1 Geometry of the mirror system

Figure 1 shows the geometry of the Nanoprobe Mirror System. Both mirrors deflect the beam horizontally. The first mirror, M1a, deflects the beam outboard. It must be mechanically bent to provide focusing onto an aperture 10 m downstream. The second mirror, M1b, reflects the beam inboard. It has a plane surface, and is used to redirect the exit beam direction to be parallel to the incident beam. Both mirrors must be mounted on a single platform. The gap between the mirrors must be 2.4 mm, as shown in Figure 1. The center-to-center distance of the mirrors must be 700 mm to allow M1b to accept the full beam reflected by M1a for all grazing angles between 2.4 mrad and 6 mrad. During operation, the grazing angle will be adjusted by rotating the platform around the center of M1a. The motions of the mirror system are specified below.

2.2 Substrates

Both mirrors must be constructed from single crystal silicon substrates. M1a must have a useful surface length of 300 mm (see Figure 2). M1b must have a useful surface length of at least 900 mm to intercept the beam reflected from M1a for all grazing angles. The full physical length of the mirror substrates can be longer to allow mounting, chamfers etc. For the total power calculations given in Appendix 1, we have assumed illumination along the full physical length of M1a, taken to be 400 mm for the purpose of this estimate.

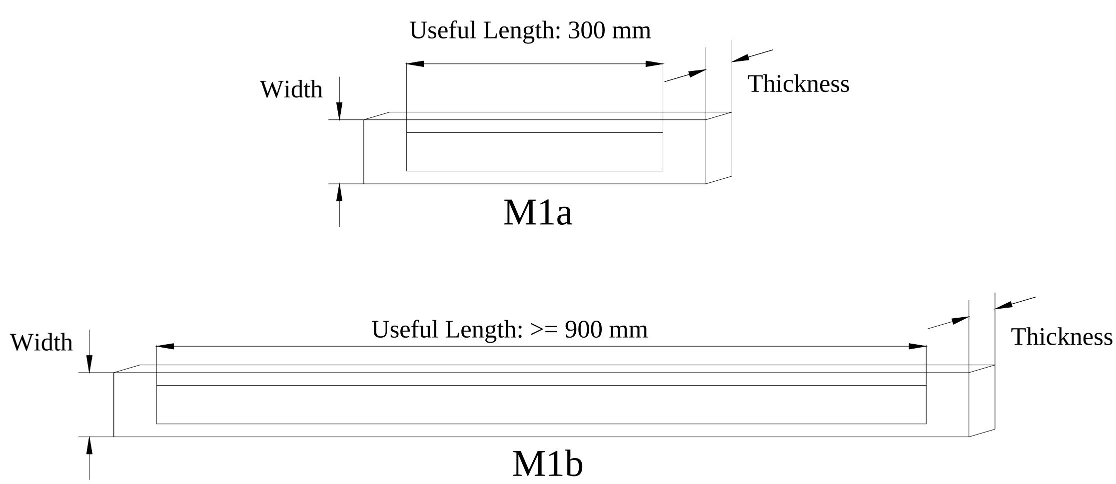

Figure 2. Dimensions and geometry of M1a and M1b mirrors. The useful length is determined by the beamline optics. The width and thickness of the mirrors should be optimized based on thermal and mechanical considerations.

The width of M1a and M1b must be sufficient for three reflective stripes with a center-to-center spacing of 15 mm, as shown in Figure 3. The exact width of the mirrors should be determined by the supplier based on thermal and mechanical performance. The thickness of each mirror should be determined by the supplier from thermal and vibrational analyses of M1a and M1b, and considerations for substrate stiffness required for polishing and by the bending mechanism for M1a.

To optimize the reflectivity of the mirror system over the range of photon energies of operation, substrate roughnesses consistent with achieving the roughness specifications for the coated stripes (section 2.4) are required for each mirror.

2.3 Figure

The figure of the first mirror, M1a, is flat when unbent. It must be bent mechanically so that the useful length has an approximately elliptical shape to provide focusing of the source 30 m upstream of M1a onto the aperture 10 m downstream, for a range of grazing angles θ of the ray at the center of the mirror between 2.4 mrad and 6 mrad. The figure of the second mirror, M1b, must be flat over its useful length.

The total of all figure errors within the useful length of both mirrors must be 2.5 μrad (σ RMS) or better. This includes figure errors of the unbent mirror M1a, the bending errors of M1a, the figure error of M1b, thermally induced slope errors of both mirrors under operating conditions, and all other effects such as vibrations.

2.4 Mirror Coatings

Both mirrors must have three reflective stripes over their useful length. The stripes must be centered on the central axis of the mirror, 15 mm above the central axis, and 15 mm below the central axis, respectively. The useful width of each stripe must be 8 mm or larger (see Figure 3). The materials for the reflective surfaces of the stripes must be silicon (e.g. uncoated), chromium and platinum. The arrangement of the stripes should be determined based on coating procedure. The thickness of the reflective chromium and platinum coatings must be between 500Å and 1000 Å. The coated stripes must have a roughness of 2Å (σ RMS) or better. The useful width of all stripes must be protected from accidental deposition of other materials on top of the reflective material during the coating process. No denser material can be present under the reflective coatings. A chromium layer of at least 200 Å thickness must be below the platinum stripe.

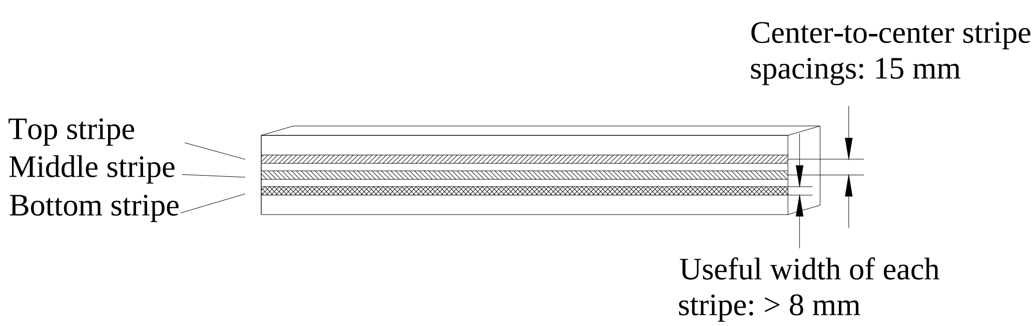

Figure 3: Mirror Coatings.

2.5 Cooling

Both mirrors must be side-cooled with water. The cooling geometry must be designed to provide thermally induced slope errors that are consistent with the specifications given elsewhere, for the range of operating power conditions listed in Appendix 1, table A1. The cooling geometry, in conjunction with positioning of fixed masks, must also allow the mirror system to handle the worst-case thermal conditions described in Appendix 1 without damage.

2.6 Integrated Masks

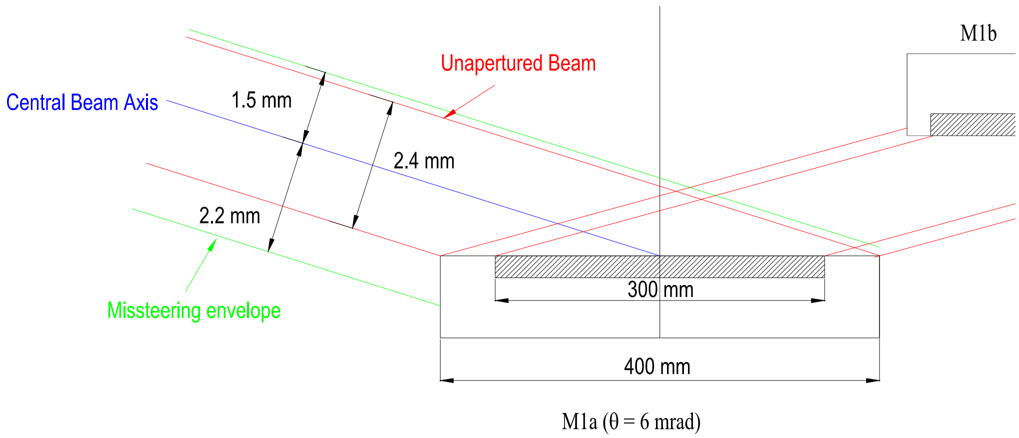

Figure 4: Horizontal dimensions of the unapertured incident undulator beam, including worst-case missteering conditions (Top view). Anamorphic representation with an aspect ratio of 100:1 for vertical:horizontal dimensions. For illustration purposes, M1a is drawn with a physical length of 400 mm, centered on the ideal beam axis, and positioned to a grazing angle of 6 mrad. The maximum missteering envelope is drawn in green. The unapertured size of the incident beam is drawn in red. As shown, both the upstream side of M1a and the upstream side of M1b could be exposed to direct undulator beam.

Water-cooled masks must protect each mirror, as well as other mirror system components, to prevent undulator beam from striking any surface other than the optical surfaces of the mirrors. The masks must be able to (i) handle the heatload encountered during normal operation, and (ii) protect the mirror system from damage for worst-case thermal conditions (see Appendix 1) if the undulator beam is missteered and/or the mirror system is misaligned.

During normal operation, M1a is fully illuminated, and the mirror system is positioned within its normal operational positions. Mask areas close to the optical surfaces should therefore be designed with relatively shallow angles to allow continued operation if these areas are hit by x-rays.

If the undulator beam is missteered, or the mirror system is misaligned in position or angle, or any combination of these conditions is encountered, a fault condition must be reported through reading mask temperatures and vacuum in the mirror chamber, so that the beam shutters can be closed. Mask areas exposed to x-rays under missteering conditions can be designed with steeper angles to minimize the total mask length. The masks must be aligned so that they do not shadow the useful length of each mirror for any grazing angle between 2.4 mrad and 6 mrad.

Figure 4 shows the geometry of the incident undulator beam with respect to the mirror system. The mirror system is shown centered on the central beam axis, at a grazing angle of 6 mrad. A physical length of 400 mm for M1a is assumed. The unapertured diameter of the undulator beam is 2.4 mm in the horizontal direction and 2.4 mm in the vertical direction at the position of the M1a. Missteering of the undulator beam could expose areas 2.2 mm inboard and 1.5 mm outboard (i.e., in the horizontal direction) of the central beam axis to the full beam power. Additional mirror surface areas can be exposed to beam during translation or rotation motions (see below).

2.7 Motions

The platform with M1a and M1b must be mounted on two parallel slides with pivots to allow translation in x (horizontal direction) (see Fig. 5). The slide on the upstream side of the mirror system must be below the center of M1a to within +/- 10 mm along the beam axis. The slide on the downstream side of the mirror system must be close to the downstream side of the mirror chamber to restrict the possible angular range of motion and to maximize stability. A slide distance of at least 1200mm is required to avoid a mirror system configuration where the mirror surfaces are parallel to the incident beam or at negative grazing angles. Table 1 lists as example the required motion range for two different slide distances.

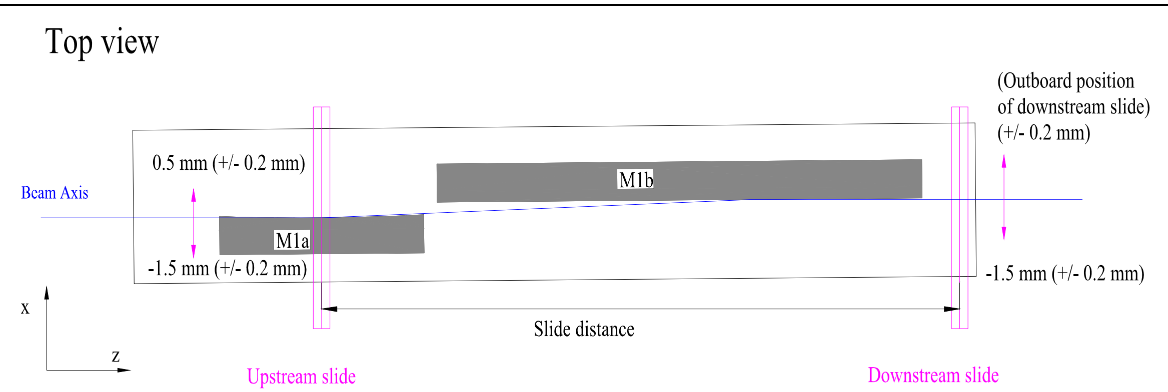

Figure 5: Horizontal translation and rotation motion of the M1 mirror system based on use of two linear slides. Positions of the inboard limit and the outboard limit of slide motion are with respect to the beam center. The maximum outboard position of the downstream slide depends on the slide distance (see Table 1).

Slide distance [mm]	Motion range of upstream slide with respect to the beam center [mm]	Motion range of downstream slide with respect to the beam center [mm]	Extremal grazing angles [mrad]
1200	-1.5 – 0.5	-1.5 – 4.8	0.4 – 8.0
1400	-1.5 – 0.5	-1.5 – 5.5	0.7 – 7.7

Table 1: Motion ranges of the upstream slide and the downstream slide for two different slide distances.

The slides must allow a horizontal translation of the center of the surface of M1a over a range of 2 millimeters orthogonal to the incident beam, from an inboard position of –1.5 mm (+/- 0.2 mm) to an outboard position of +0.5 mm (+/- 0.2 mm) with respect to the axis of the incident beam (see Fig. 5). The platform must be able to rotate mechanically to allow positioning to grazing angles between 2.4 mrad and 6 mrad. For example, for a distance between the slides of 1200 mm, with the first slide below the center of M1a, the range of motion for the first slide is from –1.5 mm (+/- 0.2 mm) to 0.5 mm (+/- 0.2 mm), and the range of motion for the second slide is from –1.5 mm (+/- 0.2 mm) to 4.8 mm (+/- 0.2 mm). The smallest possible grazing angle within the tolerances is 0.4 mrad, the largest possible grazing angle within the tolerances is 8 mrad. The horizontal motions must have a precision of 10 μm or less, and a resolution of 3 μm or less.
The mirror system must be adjustable vertically to allow positioning of the incident beam on any part of each mirror stripe. The vertical motion must have a precision of better than 100 μm, and a resolution of 10 μm or better.
A fine pitch motion of M1b with respect to M1a with a range of +/- 20 μrad, a resolution of 0.4 μrad or better, and a precision of 0.8 μrad or less must be provided.

The bender used to change the curvature of M1a must allow adjustment of the mirror figure to match all ellipses within the specified slope error for grazing angles of the central ray from 2.4 mrad to 6 mrad. During operation, the focus of the beam on the downstream aperture must be maintained when the grazing angle is changed. Therefore, repeatibility of the mirror figure must be within the slope error tolerance when returning to the same mechanical conditions. For reference, the typical average bending radius varies from 6.25 km for a grazing angle of 2.4 mrad to 2.5 km at a grazing angle of 6 mrad. To optimize operation, the motion of the mirror system required for change of grazing angle and the corresponding adjustment of the bending radius to maintain the focal length at the new grazing angle must have comparable time scales. The bender mechanism must be designed to prevent accidental overbending.

Compton scattering is a significant source of heat. When scattered radiation strikes mirror or bender supports, these components could drift, resulting in a change of mirror figure and angle. The bending mechanism and mirror supports therefore have to be designed to minimize exposure to scattered radiation, and be protected by placement of appropriate shields.

Undulator beam reflected from the mirror system must be prevented from hitting unprotected beamline components. Therefore, appropriate hard stops must be implemented to prevent the system from rotating the mirror surfaces to angles smaller than 0.4 mrad or larger than 8.0 mrad. In particular, hard stops must be placed to prevent exposure of mirror components not protected by masks to incident or reflected undulator beam. The hard stops must be easy to access to allow adjustment during final alignment after the mirror system has been commissioned.

All motions must be motorized, monitored via encoding devices, and equipped with limit switches and hard stops. All motors used must be 4-phase stepping motors with 10’ pigtail cables, and without connectors. Each motion must be encoded with an absolute encoding device, such as a glass slide. In addition, rotary shaft encoders should be used wherever practical. Limit switches must be normally closed, and adjustable in position. Piezoelectric actuators can be used for the fine-pitch motion of M1b. The contractor must specify all hardware to allow checking for APS compatibility.

All electrically energized systems should be listed by a nationally recognized testing laboratory (NRTL). If integrated assemblies of electrical components have not be tested, supplier must be able to demonstrate that the assemblies or individual components have been constructed according to applicable standards such as those associated with Underwriters Laboratories (UL), the American National Standards Institute (ANSI), the Institute of Electrical and Electronic Engineers (IEEE), the National Electrical Manufacturers Association (NEMA), Semiconductor Equipment Manufacturers International (SEMI), or comparable standards organizations located outside the United States.

2.8 Vacuum Requirements

All parts of the system such as mirror optics, coating materials, manipulators, potential in-vacuum motion parts etc. must be compatible with an ultra-high vacuum ($< 5\cdot10^{-10}$ torr). They should be capable of withstanding a chamber bakeout of 24 hours at 150°C. After bakeout, the mirror outgassing rate must not exceed $2\cdot10^{-7}$ torr·l/sec. Organic adhesives and sealants which could result in contamination of the mirror surface shall not be incorporated into the in-vacuum assembly. No material that degrades under the radiation environment encountered in an APS undulator beamline shall be used for the mirror or its mounting and attachments. All materials used must be disclosed to and approved by the APS technical representative. Included with this document is a copy of the APS vacuum policy document. No direct liquid-to-vacuum seals are allowed for chambers attached to the APS storage ring.

To allow compatibility with the beamline vacuum system, we prefer use of ion pumps from Gamma Vacuum LLC, and gauges from Helix Technology Corp.

2.9 Other requirements

The mirror system is located in a narrow section of the First Optical Enclosure. The distance of the beam center from the shielding wall inboard of the mirror system is 495 mm (see Fig. 6). The maximum inboard extension of the mirror system from the beam center should therefore be less than 470 mm. The distance of the beam center from the outboard side wall of the hutch is 1200mm, of which up to 800 mm could be used for the mirror system. The mirror system from flange to flange must have a total length of less than 1700 mm.

The input and output flanges must be 6 inch conflat (MDC # 110026 or approved equivalent). Input and output flanges shall have sufficient space to bolt outwards to blind holes of a 6 inch gate valve. The chamber must include at least six spare 2.75 inch conflat flanges (1.5 inch ID) with blankoffs to allow mounting of auxiliary components.

The locations of the mirrors within the housing must be surveyed and fiducialized to location marks outside of the vacuum chamber to allow for easier alignment of the system. In addition, a horizontal line indicating the axis of the incident beam, and a horizontal line indicating the axis of the exiting beam must be engraved or otherwise permanently attached to the support table. Levels indicating proper horizontal alignment of the mirror system in the x and z direction must be implemented on the mounting platform. The support structure must include adjustments to allow leveling and positioning of the mirror system during installation. The chamber must include lugs/eyes for lifting.

M1a including its bender, and M1b must be removable from the support platform to allow measurement of the surface of each mirror with APS metrology equipment (see below).

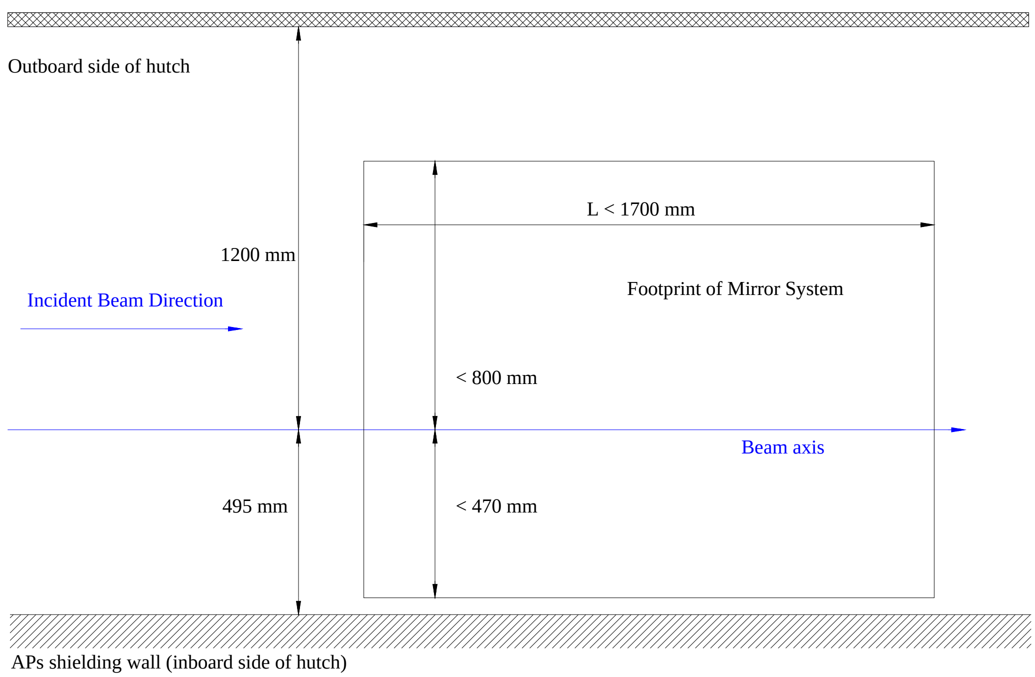

Figure 6: Relevant external dimensions for the mirror system (Top view).

The temperature of each mirror and mask must be monitored via type K thermocouples, attached in regular distances along the length of the component, and connected to the outside of the vacuum chamber via vacuum-throughputs.

3. Technical Tasks and Quality Assurance

3.1: Design (Phase 1)

The contractor must supply a design report, including a fabrication and testing plan, within 45 days after award of the contract for Phase 1. This must include manufacture drawings (> 60% completed) and detailed specifications including quality assurance and a list of subcontractors. It must also include the thermal design of both mirror substrates, the cooling geometry, appropriate thermomechanical modeling, as well as the substrate dimensions. A design review meeting will be held by Nanoprobe beamline personnel within 2 weeks after the design report is submitted. A final design report (with drawings 95% completed) must be submitted to the Nanoprobe Beamline Technical Representative within 90 days after the contract award date for Phase 1.

3.2 Fabrication (Phase 2)

Upon written approval by the Nanoprobe Beamline Technical Representative on the proposed design, fabrication and testing plan, the contractor shall furnish all materials, personnel, facilities, tools, equipment and services to fabricate, test and deliver the Nanoprobe Mirror System to the APS within 45 weeks after the contract award date for Phase 2.

3.3 Inspection

The Nanoprobe Beamline Technical Representative reserves the right to inspect any and all materials and parts used for completion of this contract. Nanoprobe Beamline representatives shall have access to the contractor’s facilities at reasonable times for inspection of progress of work.

3.4 Testing

The Nanoprobe Mirror System must be tested at the contractor’s facilities before delivery to the APS, and the test results must demonstrate that all specifications described in Section 2 have been met. The contractor must provide all necessary personnel, tools, equipment, and facilities for testing the Nanoprobe Mirror System and components. Test equipment must be calibrated and traceable to the National Institute of Standards and Technology (N.I.S.T), or equivalent national standards laboratory. The Nanoprobe Beamline Technical Representative must approve the contractor’s testing plan and procedures before the actual test takes place. The testing may be witnessed by one or more Nanoprobe Beamline representatives.

3.5 Delivery

It is the contractor’s responsibility to properly package and deliver the Nanoprobe Mirror System to sector 26 of the APS. Outgassing foam or other materials that contaminate the mirror surface must be avoided. The surface of the mirror must be protected to avoid damage during shipping. The mirror assembly should be wrapped and sealed in an inert gas environment. The contractor must provide a shipping and packaging plan (including customs procedure if necessary) at least one month prior to shipping. Acceptance of the plan will be made in writing by an authorized representative of the Nanoprobe Beamline.

3.6 Installation

It is the contractor's responsibility to install the Nanoprobe Mirror System in its location at sector 26. Nanoprobe Beamline representatives and APS staff will be available to assist in the installation process.

3.7 Onsite acceptance

Onsite acceptance will take place after delivery of the Nanoprobe Mirror System to the APS, and successful completion of the following tests:

- Measurement of the surface figure and roughness in the APS metrology lab in the presence of the contractor's representative. The APS Long-trace profiler and a WYKO 6000 interferometer will be used for characterizing slope errors and surface figure, respectively. An ADE Phase shift Micro-Xam RTS profiler with 5x and 20x objectives (ADE Phase Shift, Tucson, AZ), or a Topo-2D roughness interferometer (Wyco Corp. Tucson, AZ) will be used to measure the surface roughness at 10 different, randomly chosen locations.
- Bending test of M1a to maximum bending moment
- Transportation of the Nanoprobe Mirror System from the APS metrology lab to Nanoprobe beamline, sector 26. Installation of the Nanoprobe Mirror System into the First Optical Enclosure (26-ID-A) of the Nanoprobe beamline.
- Pump-down; vacuum and pressure testing of all fittings and seals.
- Bakeout of the mirror system for 24 hours at 150 ºC.
- Outgassing test after cool-down (leak-up curve).
- Final acceptance by the Nanoprobe Beamline.

Nanoprobe Beamline representatives and APS staff will be available to assist in the acceptance and installation process.

3.8 Modification

After the Nanoprobe Beamline Technical Representative has approved the Nanoprobe Mirror System design, no components shall be modified without written approval of the Nanoprobe Beamline. The contractor must report any non-conformance of specifications, drawings, or other contractual requirements using form ANL-311 Supplier Deviation Request. Any nonconformance that affects fabrication, testing or delivery schedule must be reported to the Nanoprobe Beamline Technical Representative within 2 business days.

4. Reports and Deliverables

The contractor must deliver the Nanoprobe Mirror System in the period specified in section 3.2. At the time of delivery, the system must have been fully tested and verified:

1) Mechanical and vacuum integrity of the vacuum chamber, and mechanical integrity of the support structure.
2) All motions and their tolerances
3) The functionality of any encoder, homing or limit switch, and
4) The quality of the optical surfaces and the functionality of the bending mechanism.

Upon arrival at the APS, at least one technical personnel of the contractor must come to the APS for the initial on-site acceptance.

4.1: Deliverable Documents

The contractor must supply the Nanoprobe Beamline Technical Representative with:

Phase 1:

1) A design report including drawings (> 60% completed), a fabrication and testing plan, and a schedule of activities, in the period specified in section 3.1 of this SOW.
2) A final design report with drawings > 95% completed in the period specified in section 3.1 of this SOW.

Phase 2:

3) Written monthly progress reports at the end of each month, starting the first month after the contract is awarded.
4) A shipping and packaging plan one month prior to shipping.
5) A full set of final mechanical drawings and blueprints, prepared in accordance with the latest ANSI Y14.5M standard, for all mechanical components (to be delivered with the Nanoprobe Mirror System).
6) Operation manuals for the Nanoprobe Mirror System.
7) Material test reports and component certifications (to be delivered with the Nanoprobe Mirror System).
8) All manuals and warranties for second-source components, including wiring diagrams for motors and encoders (to be delivered with the Nanoprobe Mirror System).
9) Test reports verifying the mechanical/vacuum/electrical/optical components have met the specifications stated in his Statement of Work (to be delivered with the Nanoprobe Mirror System).

4.2: Hardware Deliverables

The contractor must deliver the following hardware to the Nanoprobe Beamline within the time specified in section 3.2 of this SOW.

1) A support structure including motors and drivers required for horizontal and vertical translation motions and the fine pitch motion of M1b.
2) The mirror substrates including cooling mechanisms, the bending mechanism for M1a, and the fine pitch mechanism for M1b
3) Motors and drivers required for operation of the bending mechanism for M1a and the fine pitch motion for M1b.
4) A vacuum chamber including flanges
5) An ion pumping system, including an ion pump and appropriate gauges.

5. Safety

Argonne National Laboratory has established supplemental requirements for work at the Labortory by contractor personnel. The requirements for the work in this statement of work appear in ANL Form ANL-366M, *Moderate Risk Work by Contractors on the Argonne Site - Supplemental Conditions.* The requirement for the equipment installation will likely include a 45-minute safety orientation administered by the Laboratory submission and Laboratory acceptance of a job hazards analysis (JHA or JSA) for review and acceptance. The JHA must:

1. Identify each step in the work
2. List hazards for each step
3. List risk reducing measures for each identified hazard

JHA templates are available from the Laboratory.

Appendix 1: Power conditions

A) Operating Conditions for the Nanoprobe Mirror System

Illuminated length of M1a: 400 mm Vertical beam size: 0.5 mm Twin undulator A, I = 180 mA								
Photon Energy	Mirror stripe (undulator harmonic)	Grazing angle relative to mirror surface	Total power accepted by M1a and in-plane power density		Total power accepted by M1b and in-plane power density		Total power and power density absorbed by M1b	
E [keV]		θ [mrad]	P [W]	PD [W/ mm^2]	P [W]	PD [W/ mm^2]	P [W]	PD [W/ mm^2]
3	Si (1^{st})	6.0	732	3.9	19	0.09	5	0.026
4	Si (1^{st})	4.4	445	2.4	33	0.16	6	0.033
5	Si (1^{st})	3.6	307	1.6	48	0.24	6	0.031
6	Si (1^{st})	3.0	217	1.2	41	0.21	6	0.03
7	Si (1^{st})	2.6	161	0.87	44	0.22	5	0.028
8	Si (1^{st})	2.4	127	0.69	44	0.22	4	0.022
9	Si (1^{st})	2.4	107	0.60	45	0.23	3	0.016
10	Si (1^{st})	2.4	88	0.50	45	0.23	2	0.012
11	Si (1^{st})	2.4	68	0.40	43	0.21	2	0.011
12	Si (3^{rd})	2.4	243	1.3	41	0.21	4	0.019
15	Cr (3^{rd})	2.4	204	1.1	73	0.37	7	0.039
18	Cr (3^{rd})	2.4	173	0.93	72	0.36	8	0.042
21	Cr (3^{rd})	2.4	148	0.80	75	0.37	8	0.041
25	Pt (5^{th})	2.4	204	1.1	111	0.55	16	0.082
30	Pt (5^{th})	2.4	173	0.93	105	0.53	14	0.075

Table A1: Operating conditions for the Nanoprobe Mirror System as function of photon energy. An illuminated length of 400 mm is assumed. Incident power and power density for M1a and M1b are listed. The absorbed power for M1a is the difference between the accepted powers for M1a and M1b. The absorbed power and power density for M1b is listed in the right-hand column. The horizontal size of the incident beam is matched to the acceptance of the mirror, corresponding to a size of 0.96 mm at a grazing angle of 2.4 mrad, and to a size of 2.4 mm at a grazing angle of 6 mrad. The vertical beam size is limited by slits to 0.5 mm during operation.

B) Worst-case thermal conditions

The worst-case thermal conditions are encountered for closed gap of both undulators, a synchrotron current of 180 mA, and a maximum horizontal and vertical beam size of 2.4 mm. The total power in this case is 3 kW, and the normal-incidence power density is 660 W/mm^2. If the mirror system is misaligned to a worst-case grazing angle of 8.5 mrad, the worst-case in-plane power density is 5.6 W/ mm^2.

Appendix 2: Summary of Requirements for the Nanoprobe Mirror System

- Overall layout:
  - Horizontally focusing double mirror system with fixed exit angle and adjustable grazing angle.

- Position in beamline:
  - Distance of mirror system from x-ray source: 30 m.
  - Distance of focal plane from center of M1a: 10 m.

- Mirror Substrates: Single crystal silicon.
- Cooling: Side-cooling with water.
- Gap between mirrors: 2.4 mm.
- Center-to-center distance: 700 mm.
- Useful length of mirrors:
  - M1a: 300 mm.
  - M1b: 900 mm.
- Figure:
  - M1a: Mechanically bent to elliptical shape, to provide horizontal focusing on an aperture 10 m downstream of M1a for the full range of incidence angles.
  - M1b: Plane.
  - Total figure error for double mirror system: < 2.5 μrad.
- Coatings:
  - Stripes: Si, Cr, Pt.
  - Thickness of Cr, Pt stripe: 500 Å – 1000 Å.
  - Roughness of coated stripes: 2 Å (σ RMS)
  - Vertical spacing of stripes: 15 mm.
  - Width of stripes: 8 mm.
- Motions:
  - Horizontal translation: Range 2 mm (+/- 0.2 mm). Resolution: 3 μm or better
  - Grazing angle: Range: 2.4 mrad – 6 mrad. Resolution: (determined by horizontal translation)
  - Range of vertical translation: Allow positioning of incident beam on all stripes
  - Fine pitch M1b: Range: +/-20 μrad Resolution: 0.4 μrad
- Bender: Elliptical bending of M1a, to provide focusing on an aperture 10 m downstream of the mirror system for all grazing angles between 2.4 mrad and 6 mrad
- Total system length: < 1700 mm
- Total system width: < 1270 mm
- Inboard extension from beam center : < 470 mm