Flexural stages design for crystal monochromators and analysers at the Advanced Photon Source

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With my colleagues at APS/ANL, LCLS/SLAC, and EXFEL

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Thanks to my colleagues at APS/ANL, LCLS/SLAC, and EXFEL for the development of flexural-stage-based crystal monochromators/analysers:

Advanced Photon Source: T. S. Toellner, E. E. Alp, Y. Shvyd'ko, J. Ilavsky, P. L. Lee, S. D. Shastri, S. Kearney, J. Anton. D. Nocher, R. Ranay

UHV double crystal monochromators: APS 8-ID: S. Narayanan, A. Sandy, and et al

APS 16-BM: W. Yang, E. Rod, G. Shen, and et al

LCLS/SLAC: A. Robert, D. Fritz, and et al

EXFEL: X. Dong, G. Galasso, H. Sinn, and et al

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Outline

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  - *ACCM for high-resolution x-ray monochromators*
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- *UHV ACCM for x-ray double crystal monochromators*
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  - *Cryo-cooling x-ray double crystal monochromators*
    - *EXFEL*
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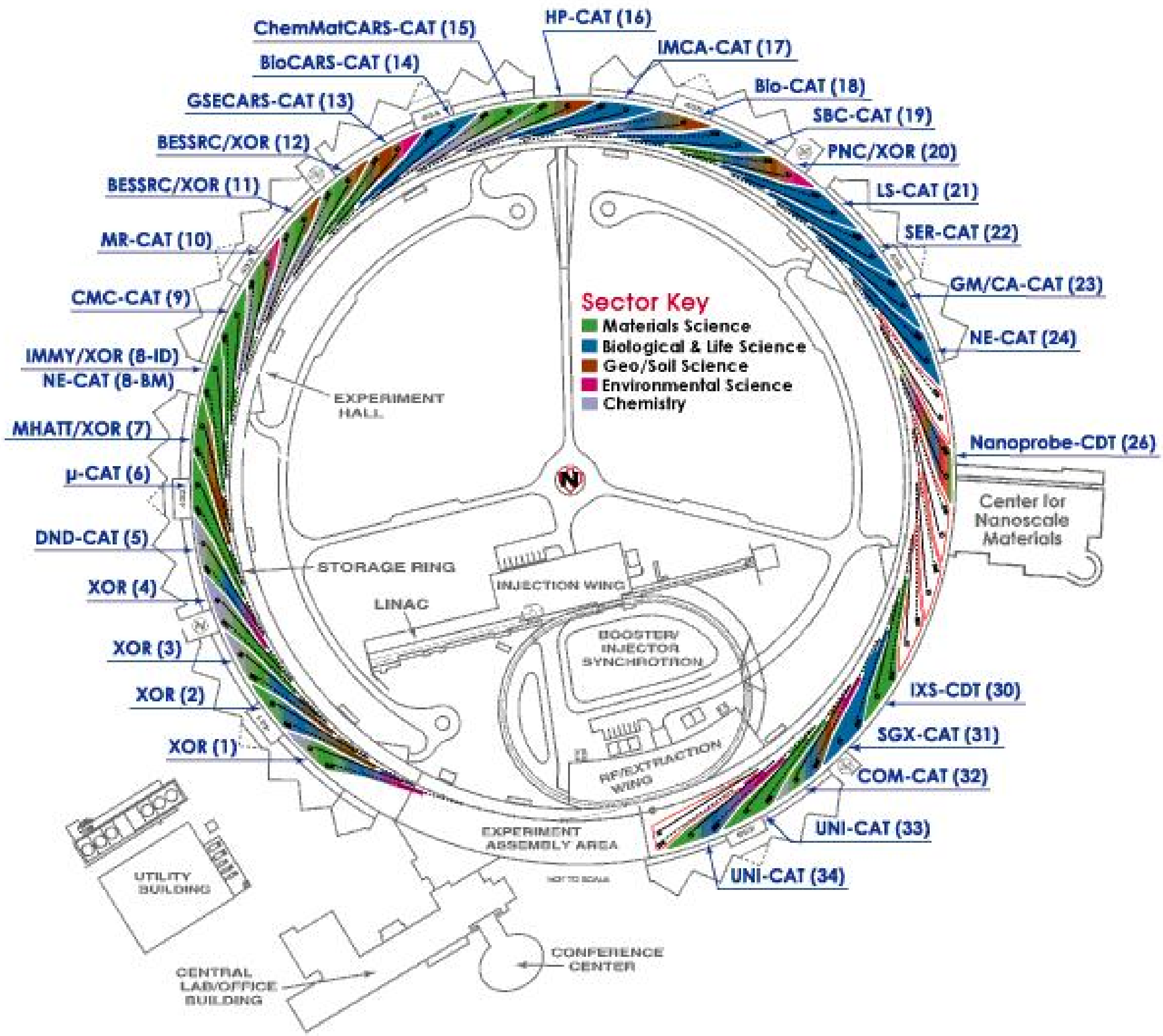
Introduction

Introduction



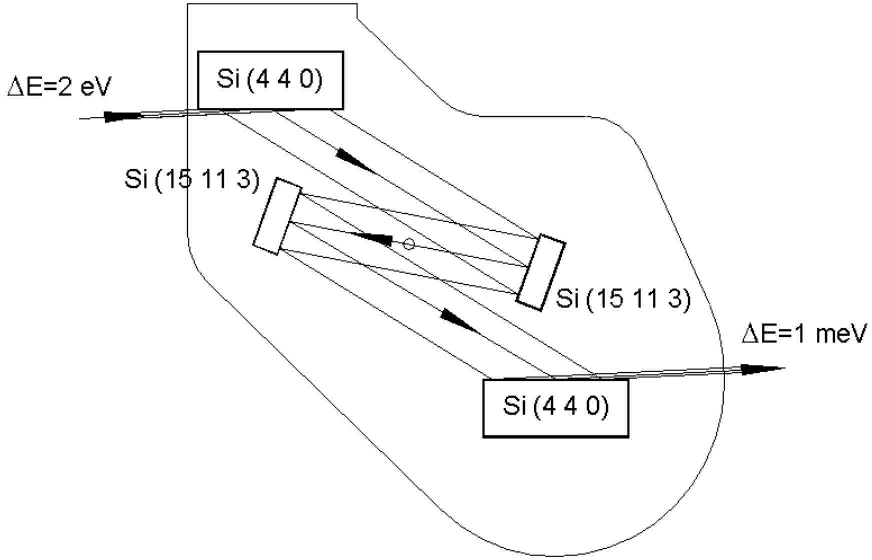
Weak-link-based Artificial Channel-Cut Crystal Mechanism

Supported by Argonne LDRD project, there are four major nanopositioning techniques developed at the APS since 1999:

- *A novel laser Doppler encoder system with multiple-reflection optics for sub-100-pm and 10-nrad-level linear and angular displacement measurement.*
- *A rotary, high-stiffness, weak-link mechanism with stacked thin metal sheets having 10-nrad driving sensitivity with excellent stability.*
- *A linear, high-stiffness, weak-link mechanism with stacked thin metal sheets having sub-100-pm driving sensitivity with excellent stability.*
- *A digital-signal-processor (DSP)-based, real-time, closed-loop feedback system for active relative vibration control on the nanometer scale.*

Weak-link-based Artificial Channel-Cut Crystal Mechanism

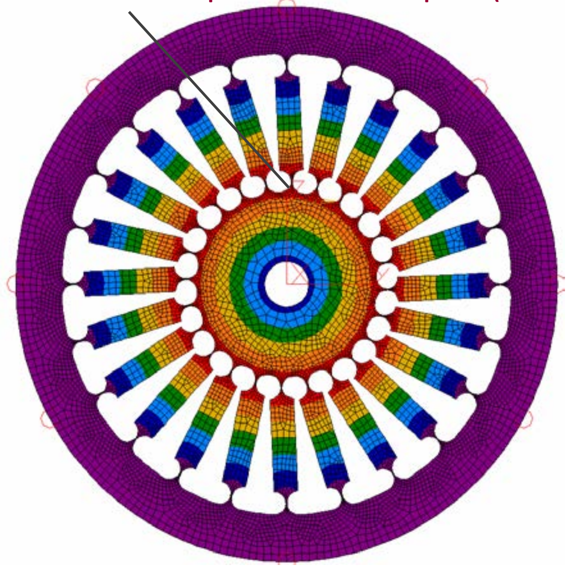
In 1999, to overcome the obstacles in developing a 4-crystal in-line high-resolution hard x-ray monochromator using a nested channel-cut crystal geometry with meV bandpass, the first high-stiffness weak-link mechanism with stacked thin-metal sheets was developed for the APS high-energy-resolution beamline 3-ID. The precision and stability of this mechanism allowed us to align or adjust an assembly of crystals to achieve the same performance as a single channel-cut crystal, so we called it an "artificial channel-cut crystal."

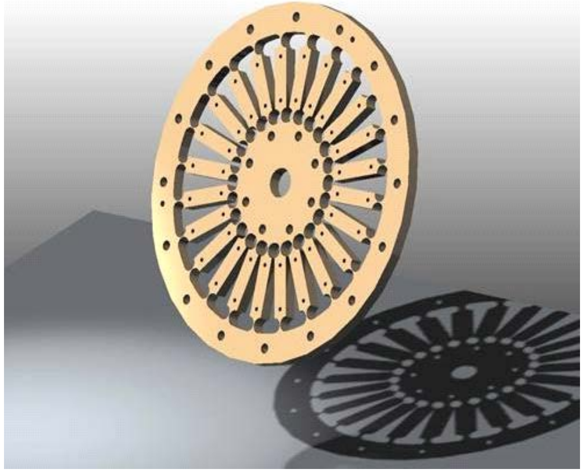


D. Shu, T. S. Toellner, and E. E. Alp, Nucl. Instrum. and Methods A 467-468, 771-774 (2001)

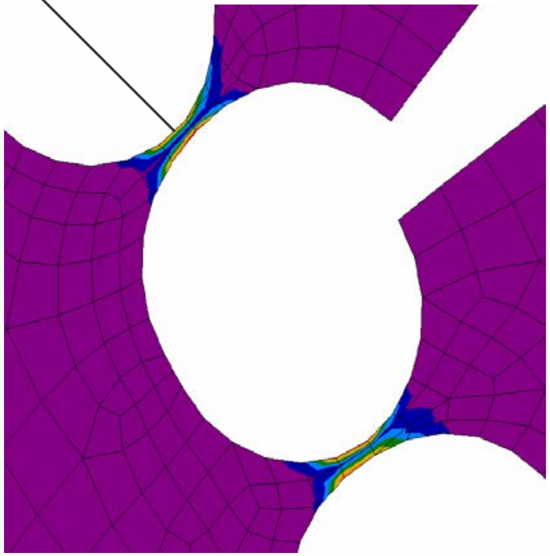
Weak-link-based Artificial Channel-Cut Crystal Mechanism

maximum displacement 94 µm (0.25 degree angular motion)





maximum von Mises stress 175 MPa



Unlike traditional kinematic linear spring mechanisms, the overconstrained weak-link mechanism provides much higher structural stiffness and stability. Using a laminar structure configured and manufactured by chemical etching and lithography techniques, we are able to design and build a planar-shape, high-stiffness, high-precision weak-link mechanism.

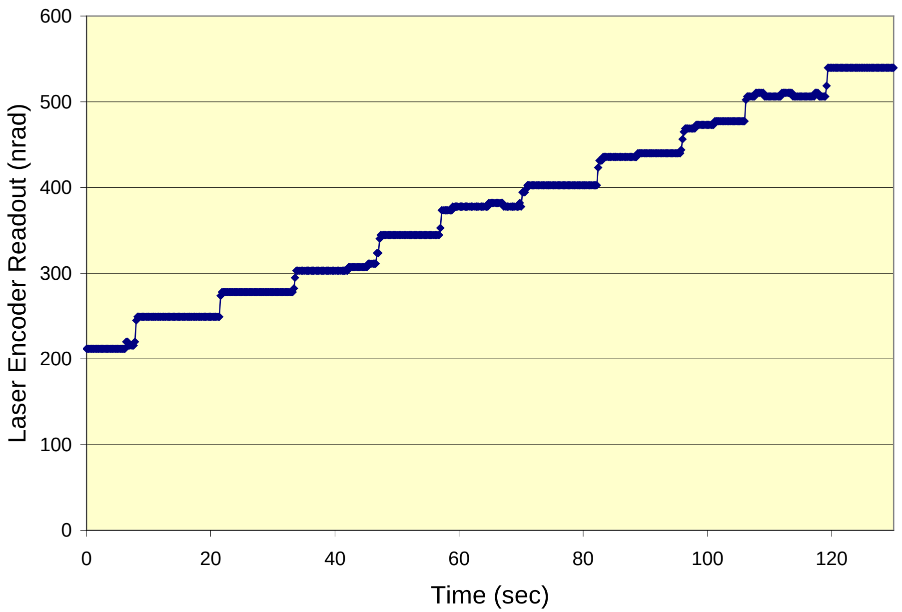
The precision of modern photochemical machining processes using lithography techniques makes it possible to construct a strain-free (or strain-limited) overconstrained mechanism on thin metal sheets. By stacking these thin-metal weak-link sheets with alignment pins, we can construct a solid complex weak-link structure for a reasonable cost.

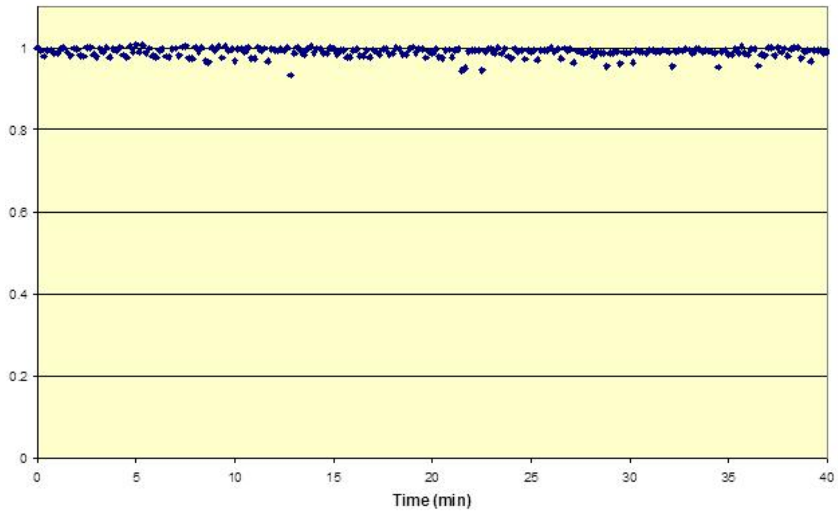
D. Shu, T. S. Toellner, and E. E. Alp, Nucl. Instrum. and Methods A 467-468, 771-774 (2001)

Test of high-stiffness angular weak-link mechanism

- Sensitivity test with a laser Doppler encoder

  A test with 33 nrad average step size





- Stability result from a x-ray experiment

  Relative intensity measured by an ionization chamber after the high-resolution monochromator (1-meV bandwidth) as a function of time. The data are corrected for the decaying current in the storage ring.

D. Shu, T. S. Toellner, and E. E. Alp, Nucl. Instrum. and Methods A 467-468, 771-774 (2001)

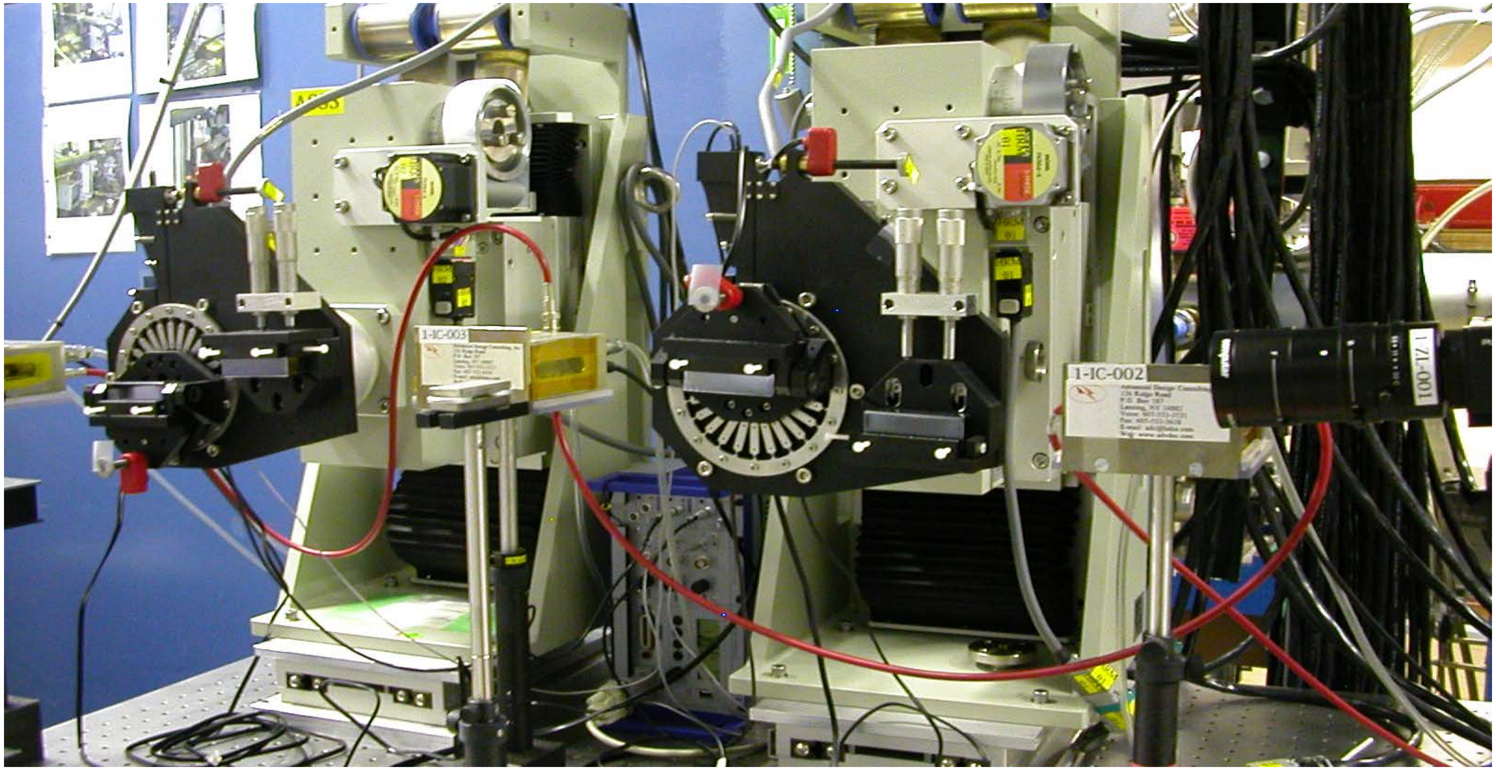
ACCM for high-resolution x-ray monochromators

Weak-link mechanism for high-energy-resolution hard x-ray monochromators at APS 3-ID

D. Shu, T. S. Toellner, and E. E. Alp, "Modular Overconstrained Weak-Link Mechanism for Ultraprecision Motion Control," Nucl. Instrum. Methods A 467-468, 771-774 (2001).
U.S. Patent granted No. 6,607,840, Redundantly constrained laminar structure as weak-link mechanisms, D. Shu, T. S. Toellner, and E. E. Alp, 2003.
D. Shu, T. S. Toellner, E. E. Alp, J. Maser, J. Ilavsky, S. D. Shastri, P. L. Lee, S. Narayanan, and G. G. Long, "Applications of Laminar Weak-Link Mechanisms for Ultraprecision Synchrotron Radiation Instruments", AIP CP879, 1073-1076 (2007).

ACCM for high-resolution x-ray monochromators

Weak-link mechanism for high-energy x-ray monochromator at APS 1-ID-B

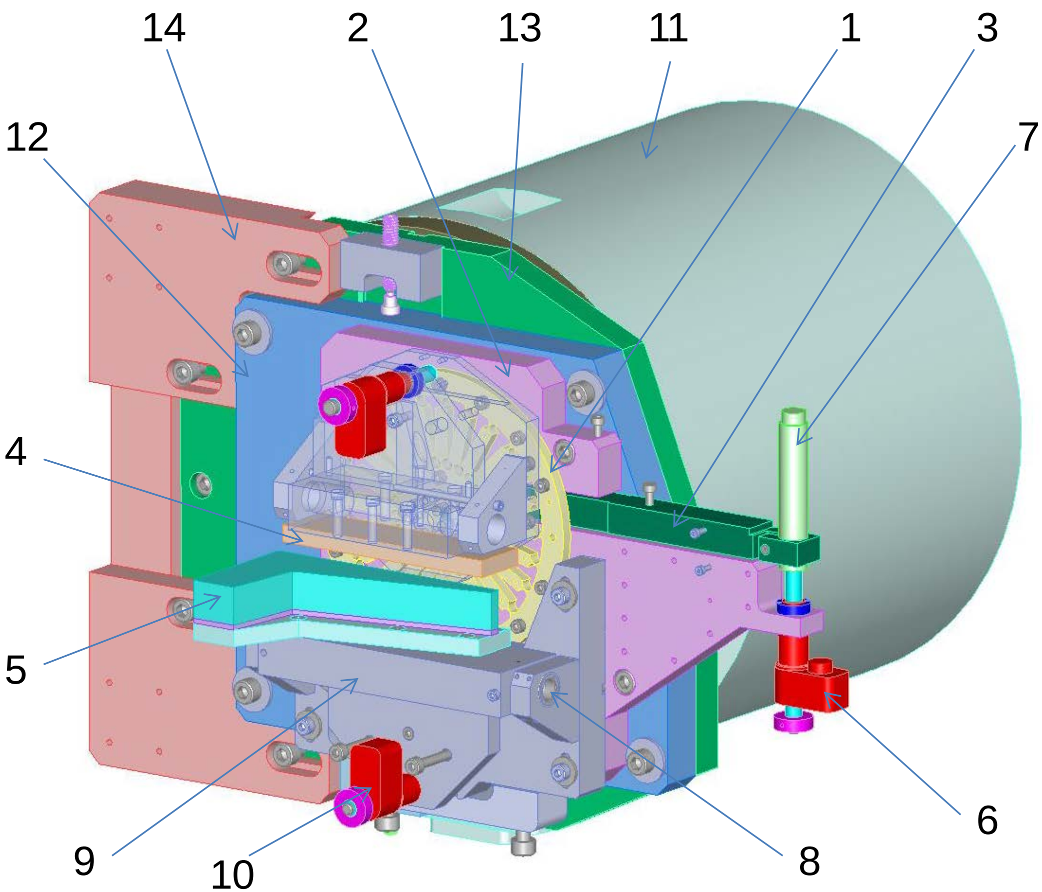


Photograph of a high-energy x-ray monochromator with four crystal reflections constructed at APS XOR beamline 1-ID-B. It shows a high-energy (50-100 keV) high-resolution x-ray monochromator with four crystal reflections constructed at APS beamline 1-ID-B, which has been used for resonant powder diffraction and stress/strain studies**.*

** Y. Zhang, A. P. Wilkinson, P. L. Lee, S. D. Shastri, D. Shu, D. –Y. Chung, M. G. Kanatzidis, J. Appl. Cryst. 38, 433-441 (2005).*
*** B. Jakobsen, H. F. Poulsen, U. Lienert, J. Almer, S. D. Shastri, H. Sorensen, C. Gundlach, W. Pantleon, Science 312, 889-892 (2006).*

ACCM for high-resolution x-ray analysers

Artificial channel-cut crystal stage for the APS USAXS instrument crystal analyzer

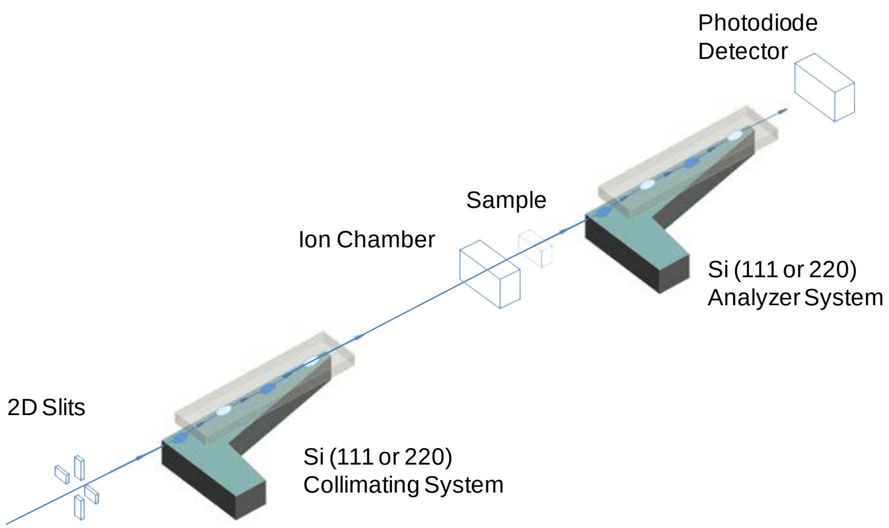


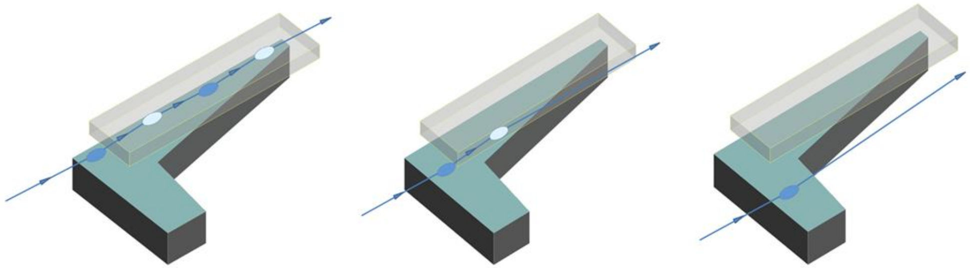
A 3D model of the artificial channel-cut crystal stage for the APS USAXS instrument crystal analyzer system: (1) high-stiffness, weak-link mechanism module; (2) base plate; (3) sine-bar; (4,5) two silicon single crystals; (6) Picomotor^{TM}; (7) Physik InstrumenteTM closed-loop controlled PZT; (8) commercial flexure bearing; (9) crystal holder; (10) PicomotorTM-driven structure; (11) Aerotech^{TM} rotary stage; (12,13) adapter plates; (14) balancing plate.

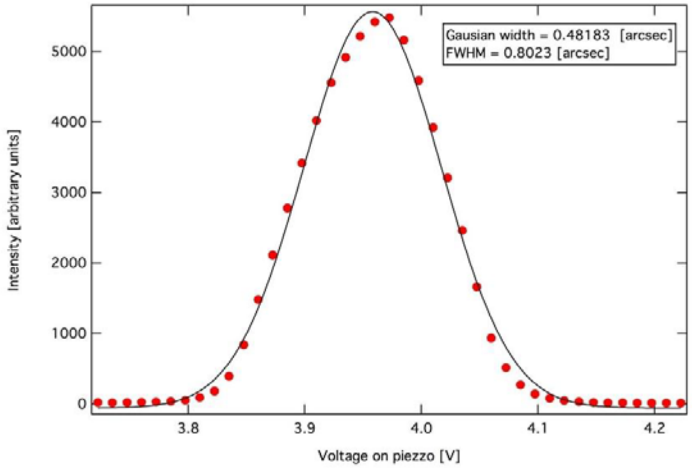
J. Ilavsky, D. Shu, P.R. Jemian, and G.G. Long, AIP CP879, 1833-1836 (2007)

ACCM for high-resolution x-ray analysers

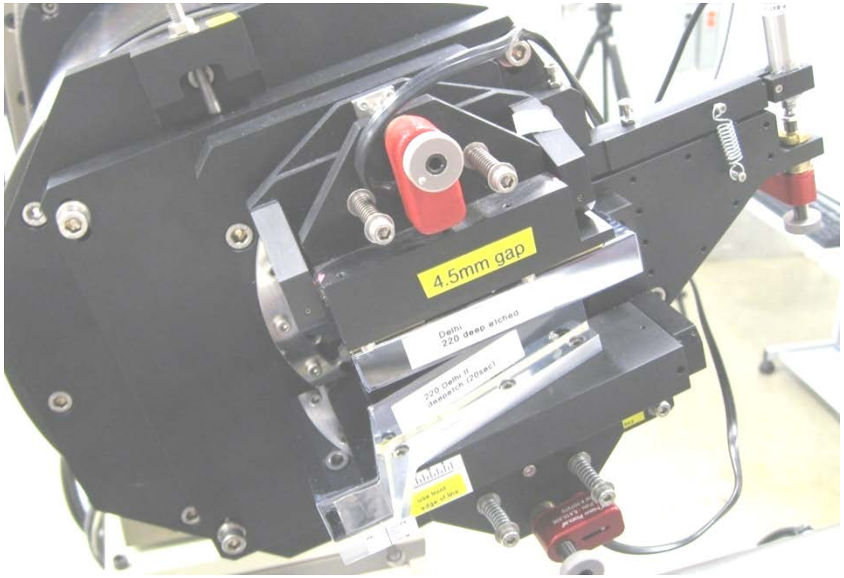
Artificial channel-cut crystal stage for the APS USAXS instrument crystal analyzer







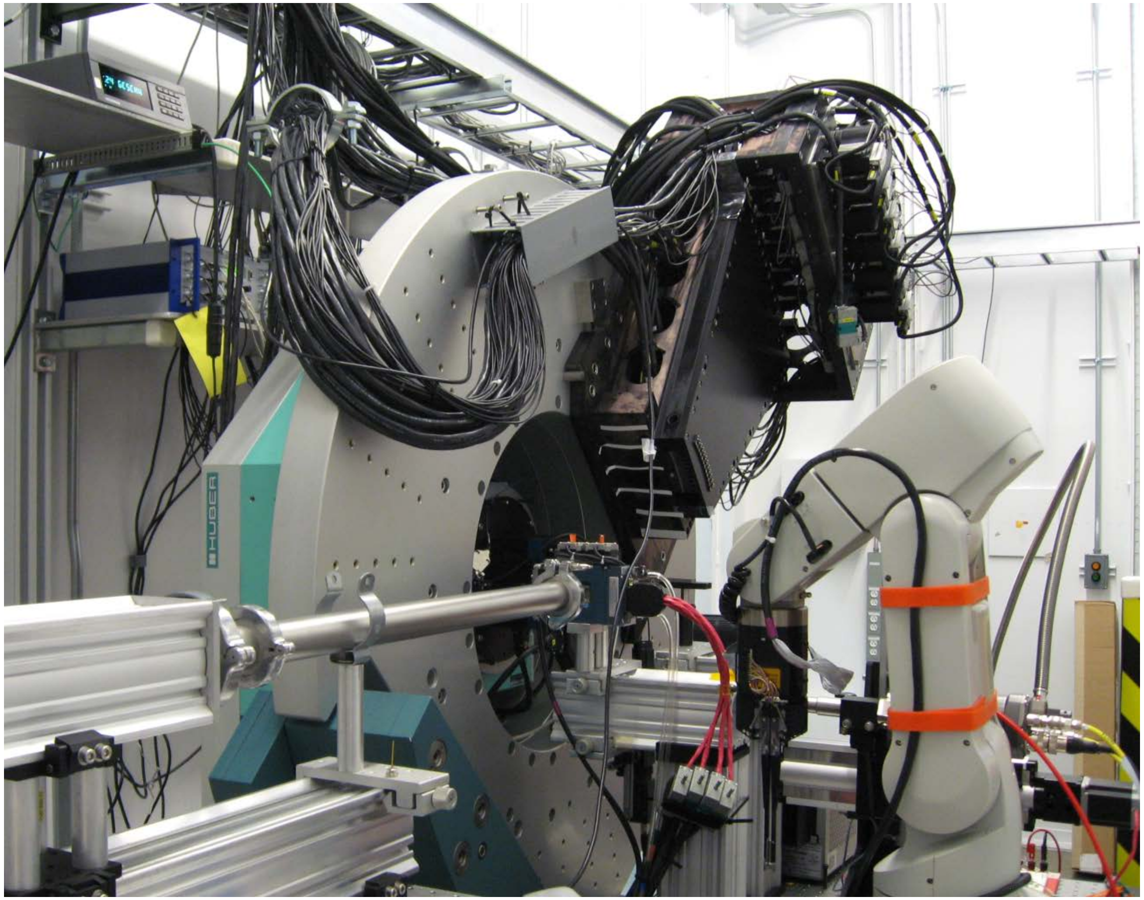
An X-ray rocking curve scan result using the artificial channel-cut crystal stage with a step size of about 300 nrad.

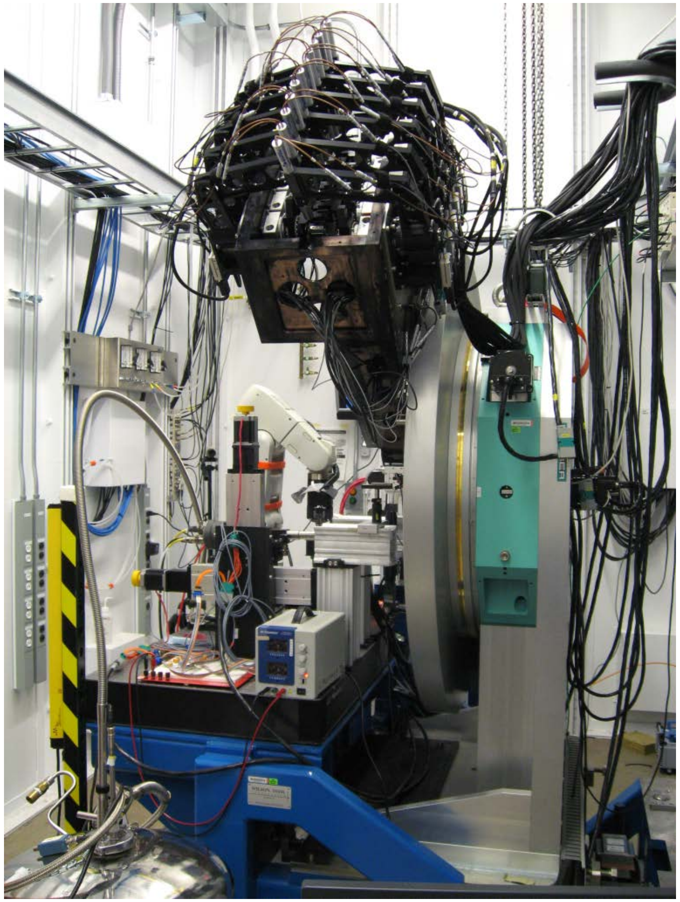


J. Ilavsky, D. Shu, P.R. Jemian, and G.G. Long, AIP CP879, 1833-1836 (2007)

ACCM for high-resolution x-ray analysers

Twelve-analyzer and detector system at APS 11-BM



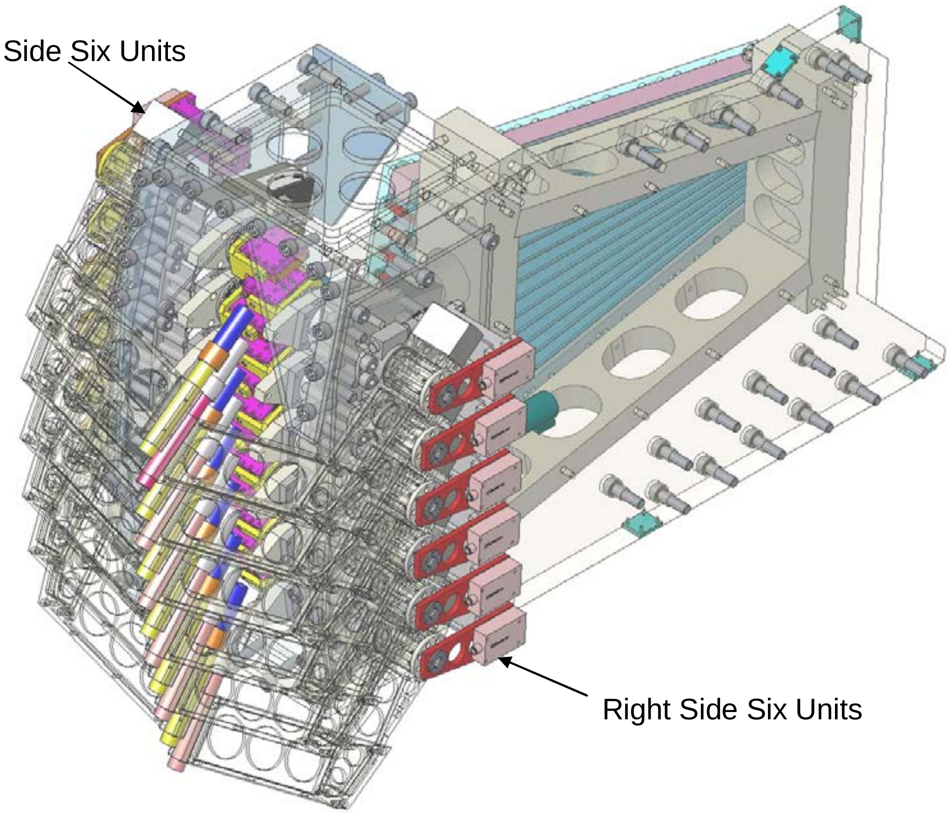


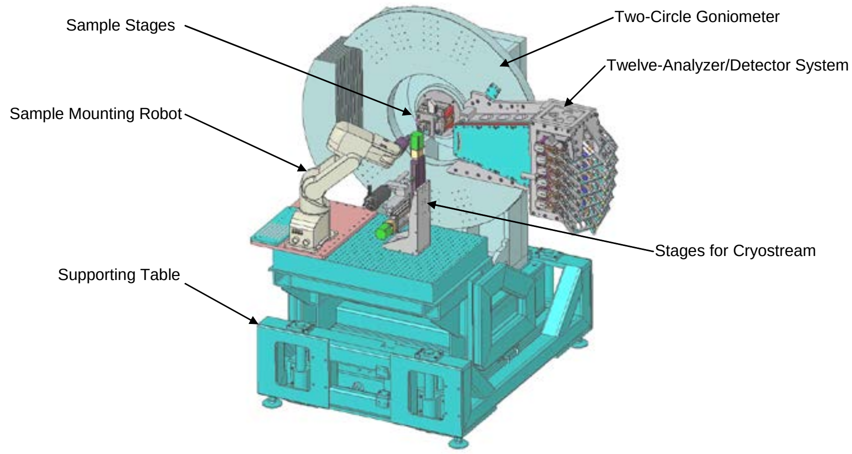
The high-resolution diffractometer has a dimension of 2600 mm (H) X 2100 mm (L) X 1700 mm (W).   The main circle of the goniometer has a vertical mounting disk with an outside diameter of 1200 mm.

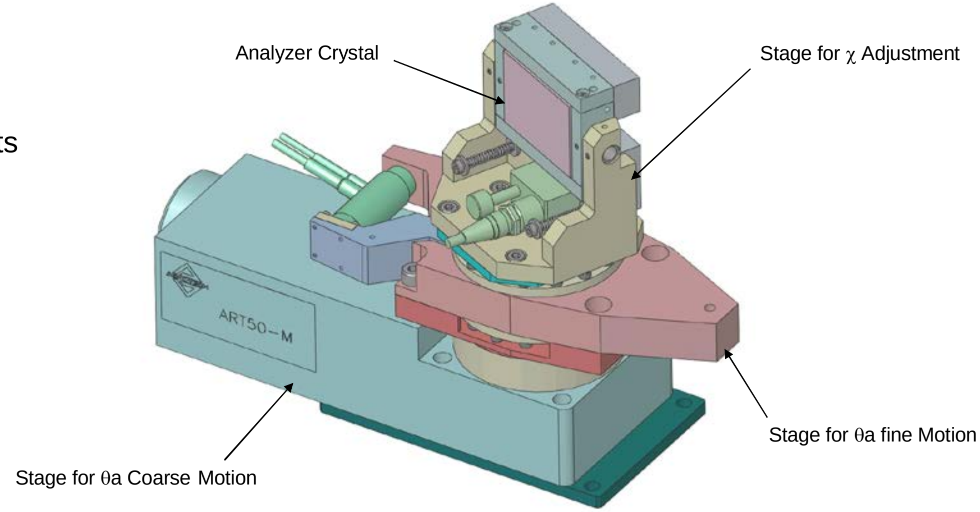
P. L. Lee et al., J. Sychrotron Rad. (2008) 15, 427-432

ACCM for high-resolution x-ray analysers

Twelve-analyzer and detector system at APS 11-BM







P. L. Lee et al., J. Sychrotron Rad. (2008) 15, 427-432
D. Shu et al., proceedings of SPIE Vol. 6665, 66650N1-8 (2007)

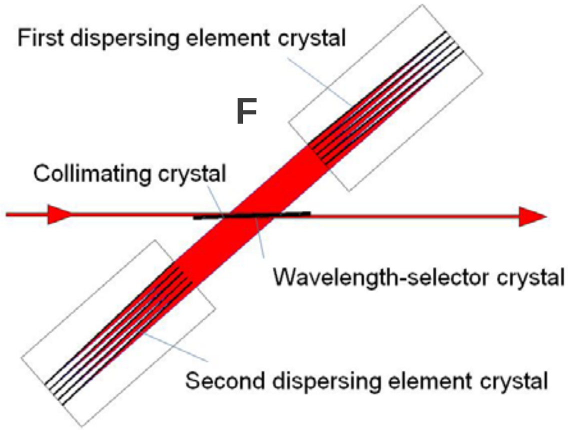
ACCM for high-resolution x-ray monochromator and analysers

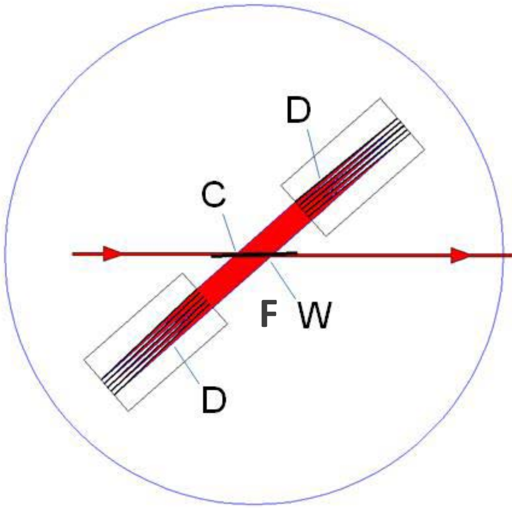
Ultrahigh-Resolution Monochromator and Analyzer for CDFDW Inelastic X-ray Scattering Spectrometer at the APS 30-ID

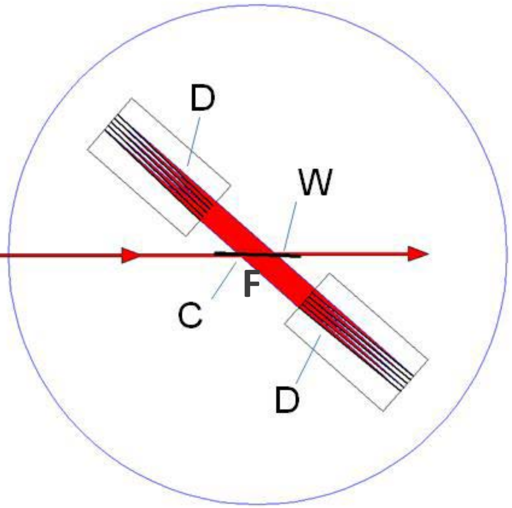
In 2006, Yuri Shvyd"ko et al. observed three effects in Bragg diffraction of x-rays in backscattering geometry from asymmetrically cut crystals:

- *exact Bragg backscattering takes place not at normal incidence to the reflecting atomic planes,*
- *a well-collimated beam is transformed after the Bragg reflection into a strongly divergent beam with reflection angle dependent on x-ray wavelength (an effect of angular dispersion),*
- *parasitic Bragg reflections accompanying Bragg backreflection are suppressed.*

These effects offer a radically new means for monochromatization of x-rays not limited by the intrinsic width of the Bragg reflection, the so called CDW and CDFDW angular-dispersive monochromators configuration. The abbreviation CDFDW stands for: C – collimating crystal, D – dispersing-element crystal (two D-crystals are used in each CDDW), F- anomalous transmission filter, and W - wavelength-selector crystal. However, there are many optomechanical design challenges on the road for turning a CDDW optical configuration into a practical instrument







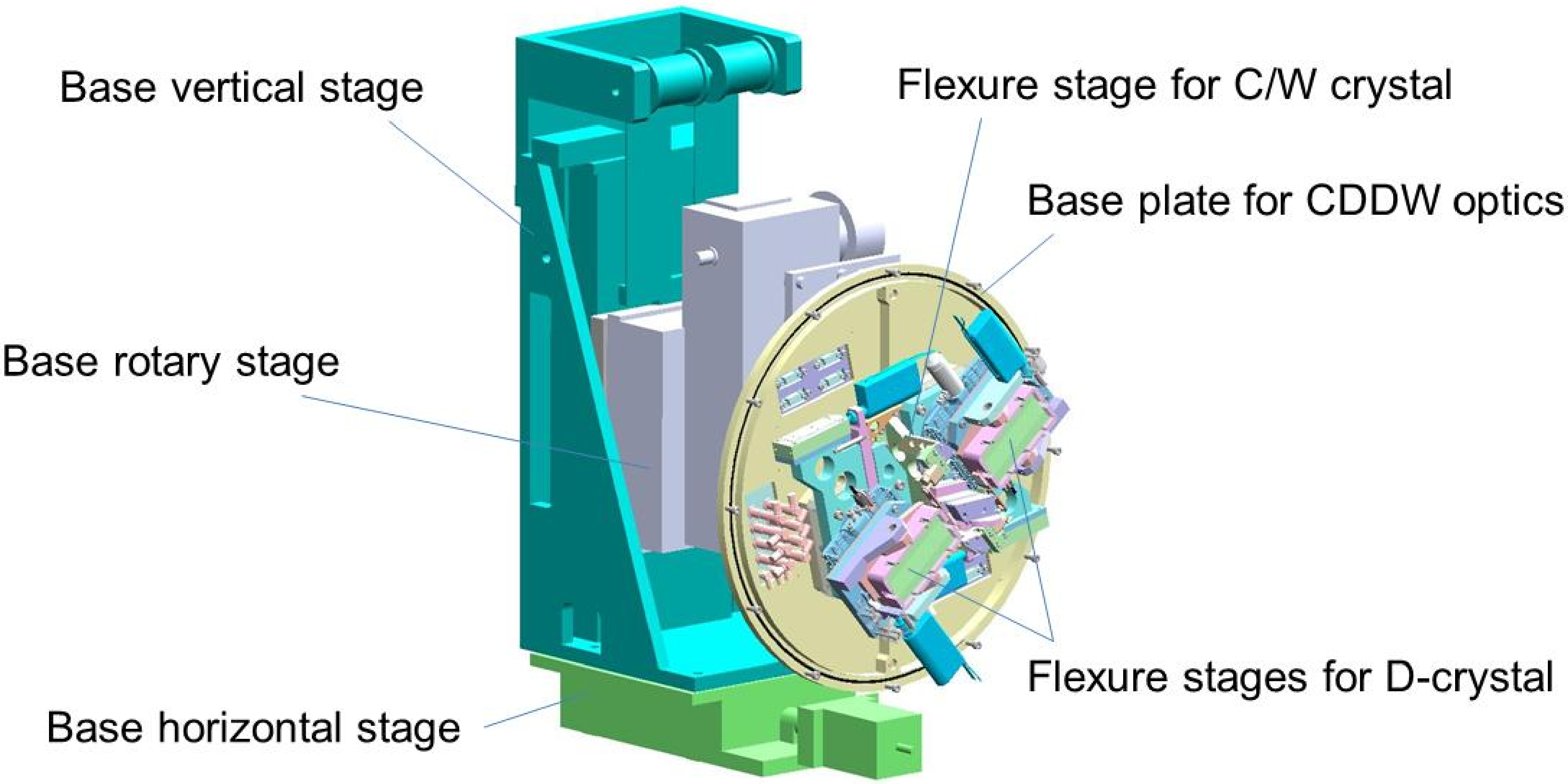
CDFDW Monochromator

CDFDW Analyzer

Y. Shvyd'ko et al., Physical Review A, 84 053823(2011)

ACCM for high-resolution x-ray monochromator and analysers

Ultrahigh-Resolution Monochromator and Analyzer for CDFDW Inelastic X-ray Scattering Spectrometer at the APS 30-ID

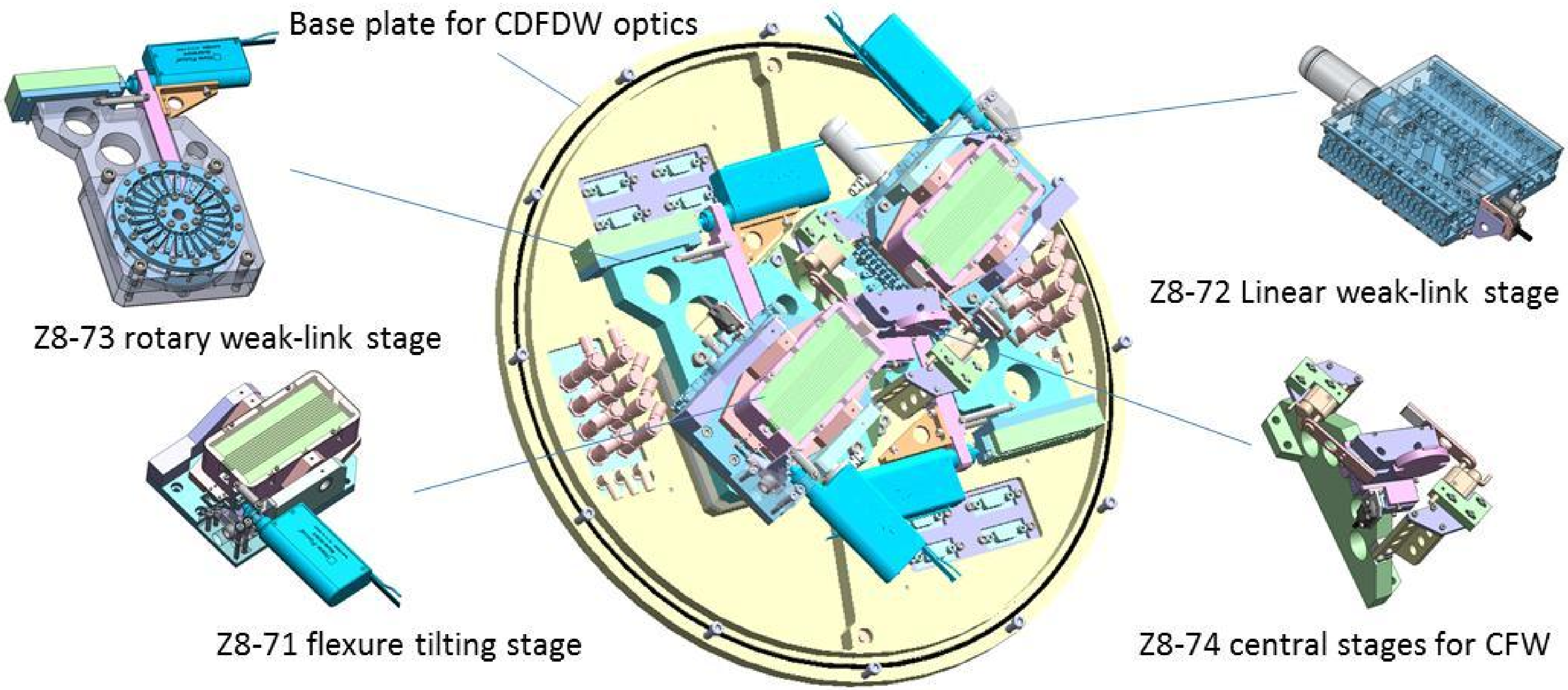


A 3-D model of the base stages for the alignment of the whole CDDW optics.

Y. Shvyd'ko et al., Physical Review A, 84 053823(2011)

ACCM for high-resolution x-ray monochromator and analysers

Ultrahigh-Resolution Monochromator and Analyzer for CDFDW Inelastic X-ray Scattering Spectrometer at the APS 30-ID

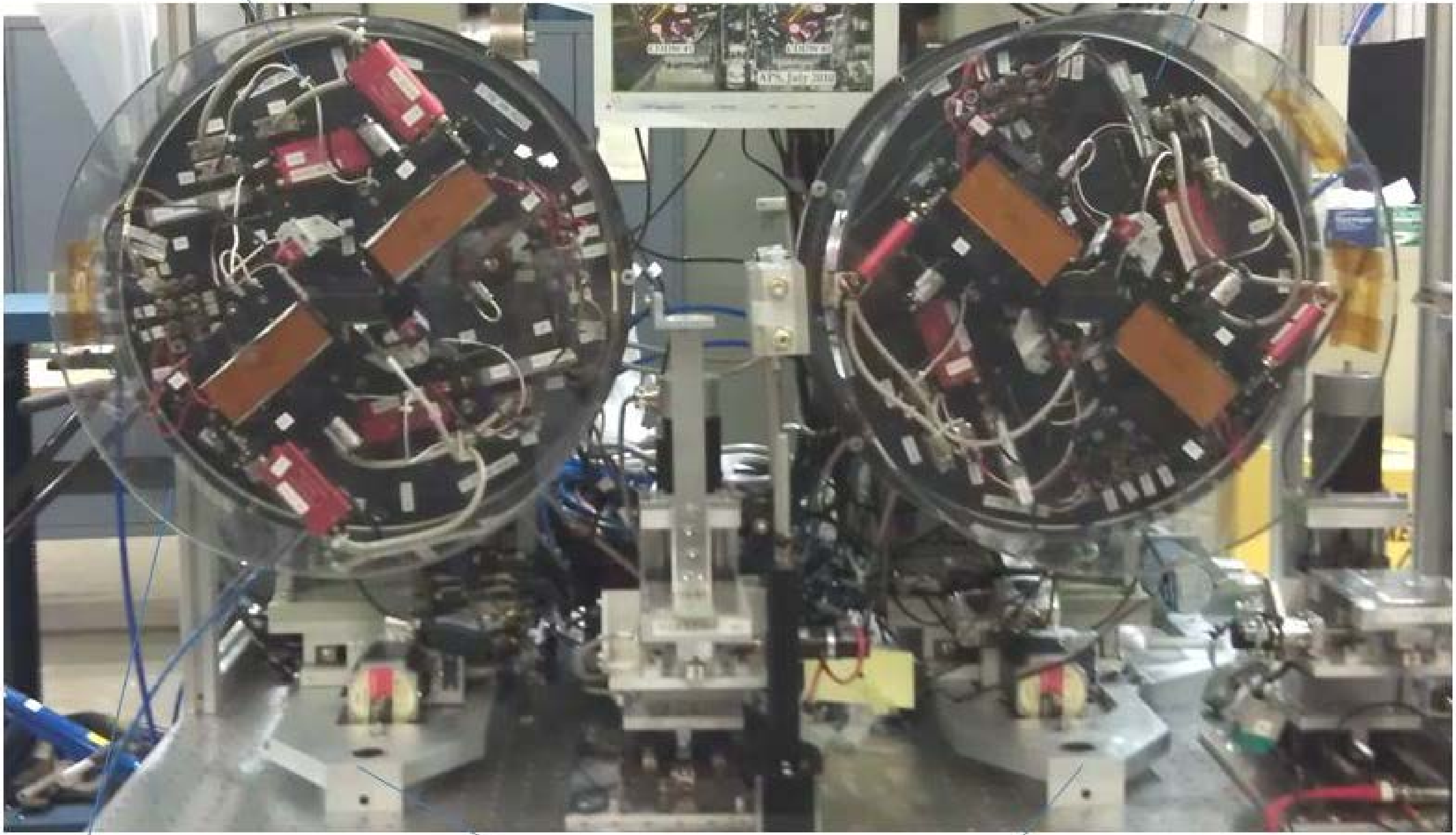


A 3-D model of the CDFDW x-ray monochromator for the prototype of the ultrahigh-resolution IXS spectrometer constructed at the APS.

Y. Shvyd'ko et al., Physical Review A, 84 053823(2011)

ACCM for high-resolution x-ray monochromator and analysers

Ultrahigh-Resolution Monochromator and Analyzer for CDFDW Inelastic X-ray Scattering Spectrometer at the APS 30-ID

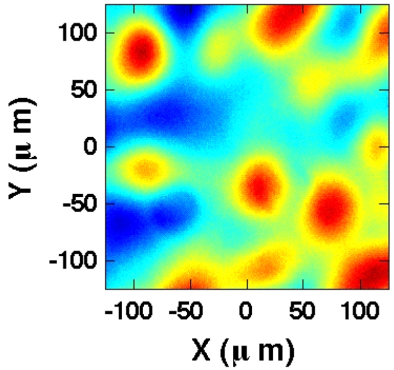


A photograph of the prototype of the ultrahigh-resolution IXS spectrometer designed, constructed, and tested at undulator-based beamline 30-ID at the APS.`

Y. Shvyd'ko et al., Physical Review A, 84 053823(2011)

UHV ACCM for x-ray double crystal monochromators

Design of the UHV X-ray Monochromator for XPCS at the APS 8-ID



• X-ray photon correlation spectroscopy (XPCS) is a brilliance-limited technique, the monochromator must preserve the beam brilliance by having highly polished diffracting faces.

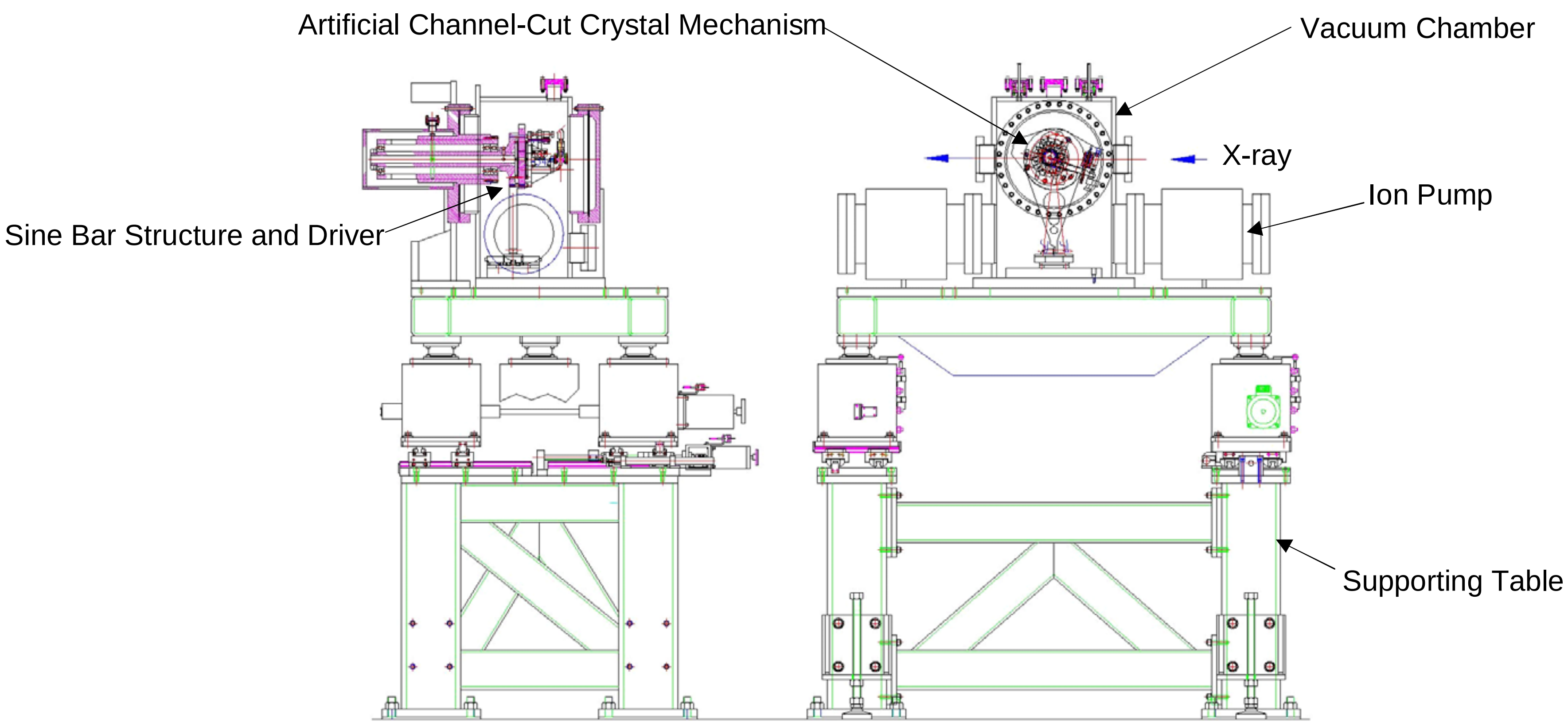
• The monochromator should also be mechanically stable so that spurious monochromator motions do not corrupt the fluctuating scattered x-ray signal arising from the sample.

• These requirements have not proven possible with either the original 8-ID-I "traditional" channel-cut design or an enhanced "Z-step" channel-cut crystal; they both produce spatially inhomogeneous (and statistically indistinguishable from each other) monochromatic beams.

S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
D. Shu et al., proceedings of SPIE Vol. 6665, 66650O1-8 (2007)

UHV ACCM for x-ray double crystal monochromators

Design of the UHV X-ray Monochromator for XPCS at the APS 8-ID

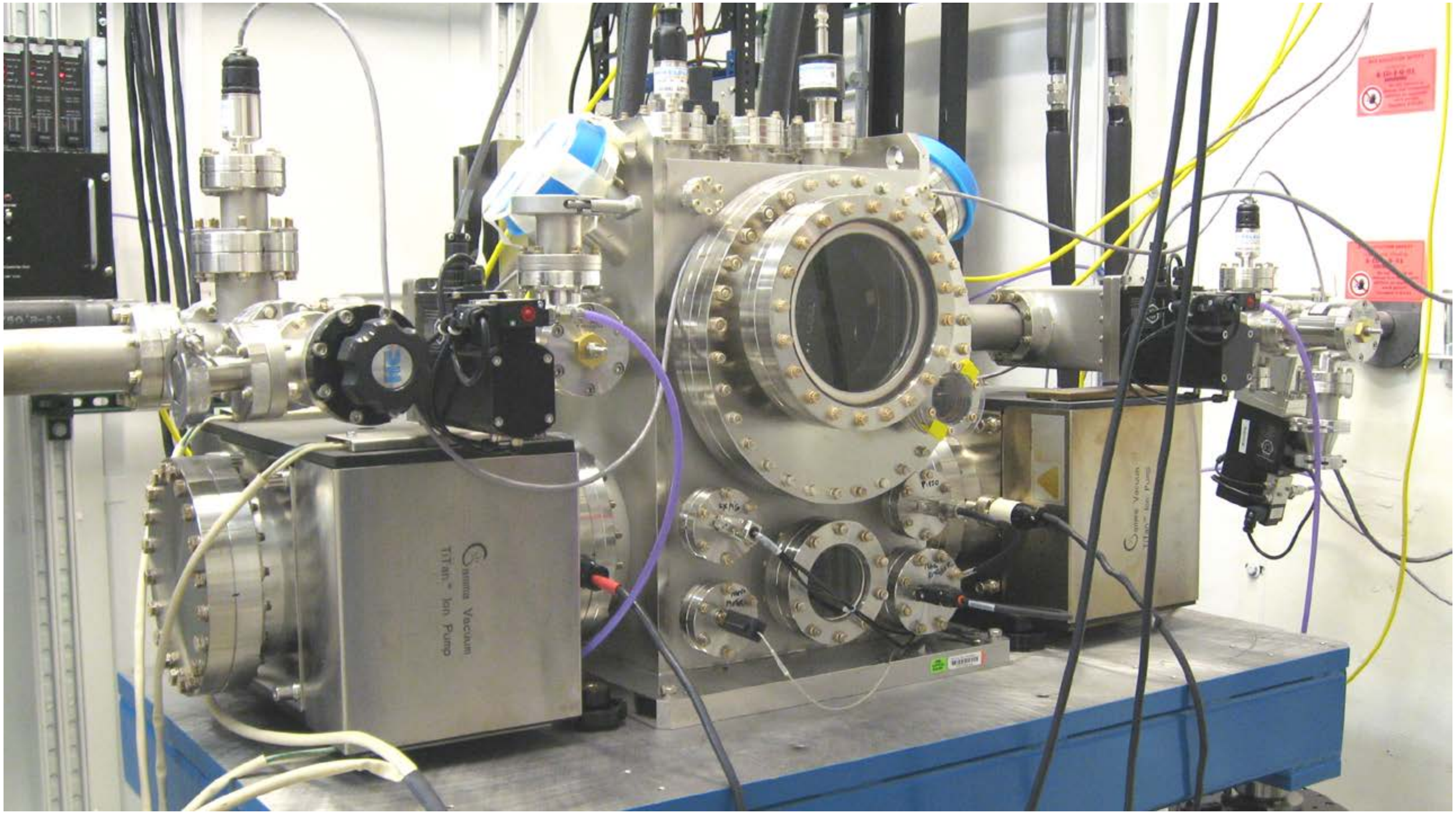


The 8-ID-I new monochromator consists of five sub-assemblies: a supporting table with five degrees of freedom motorized alignment capability, an UHV compatible vacuum chamber, a sine bar structure and its driver, an artificial channel-cut crystal mechanism, and two ion pumps.

S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
D. Shu et al., proceedings of SPIE Vol. 6665, 66650O1-8 (2007)

UHV ACCM for x-ray double crystal monochromators

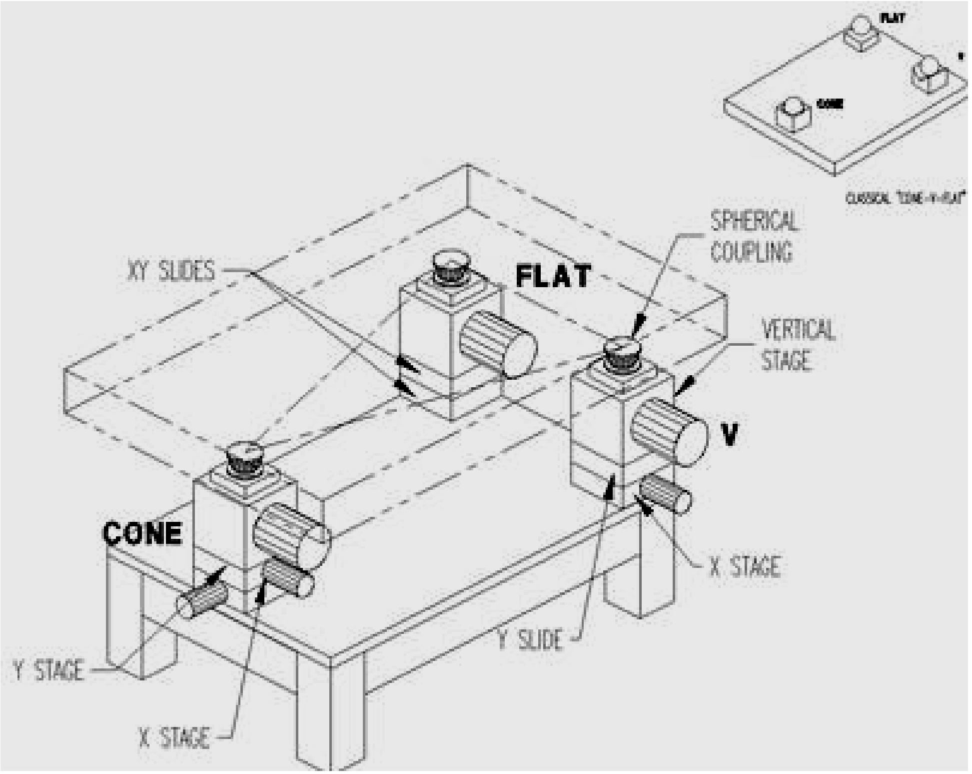
Design of the UHV X-ray Monochromator for XPCS at the APS 8-ID



A photograph of the new 8-ID-I UHV-compatible artificial channel-cut x-ray monochromator.

S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
D. Shu et al., proceedings of SPIE Vol. 6665, 66650O1-8 (2007)

UHV ACCM for x-ray double crystal monochromators



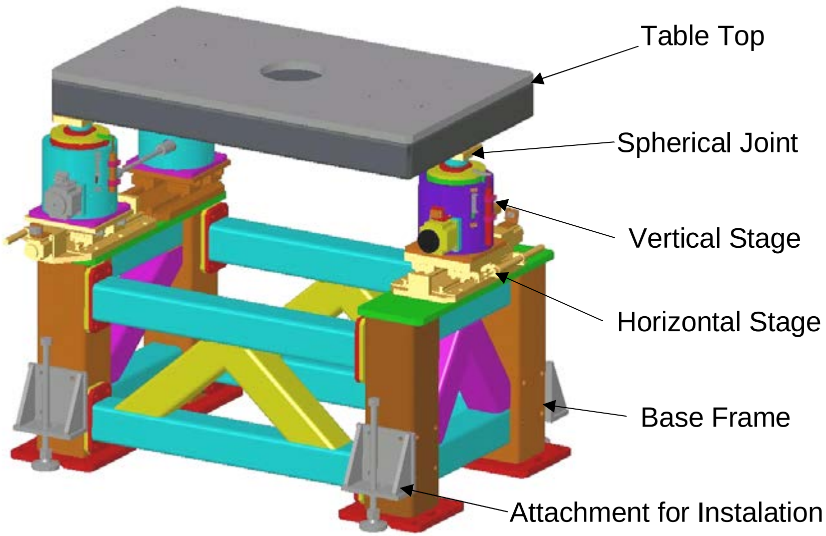
To provide five degrees of freedom alignment capability for the new monochromator crystal optics with the axis of the x-ray beam at the 8-ID-I experimental station, an APS designed standard kinematic mounting table is used as the base of the monochromator. The table's basic precision motion design uses the 3-point "cone-flat-V" kinematic mount concept obtained through the use of modular linear rolling stages and ball-bearing spherical joints as shown in the left side of Fig. 3. The "cone-flat-V" kinematic mount concept has the advantages of 3-point stability, reduced space usage, minimal motor drivers, free and unconstrained thermal expansion, and good positioning repeatability.

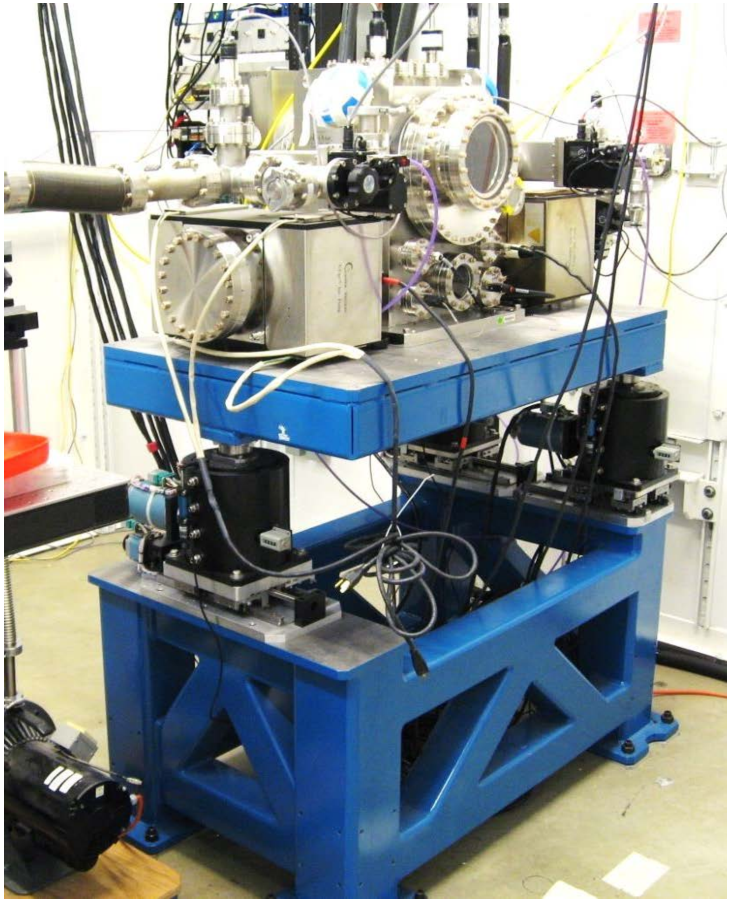
S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
D. Shu et al., proceedings of SPIE Vol. 6665, 66650O1-8 (2007)

UHV ACCM for x-ray double crystal monochromators

TABLE 1. Design specifications of the supporting table for the new 8-ID-I monochromator

Motorized stages type	Stepping-motor-driven linear stages with spring-loaded linear potentiometer encoder
Horizontal travel range	25 mm
Horizontal positioning resolution	5 micron or better
Horizontal positioning reproducibility	20 micron or better
Vertical travel range	25 mm
Vertical positioning resolution	2 micron or better
Vertical positioning reproducibility	10 micron or better
Load capacity	1000 kg





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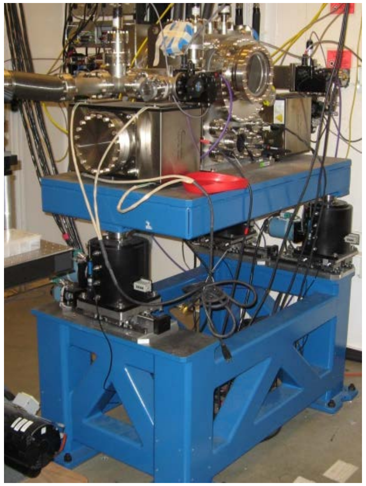
UHV ACCM for x-ray double crystal monochromators



Linear potentiometer

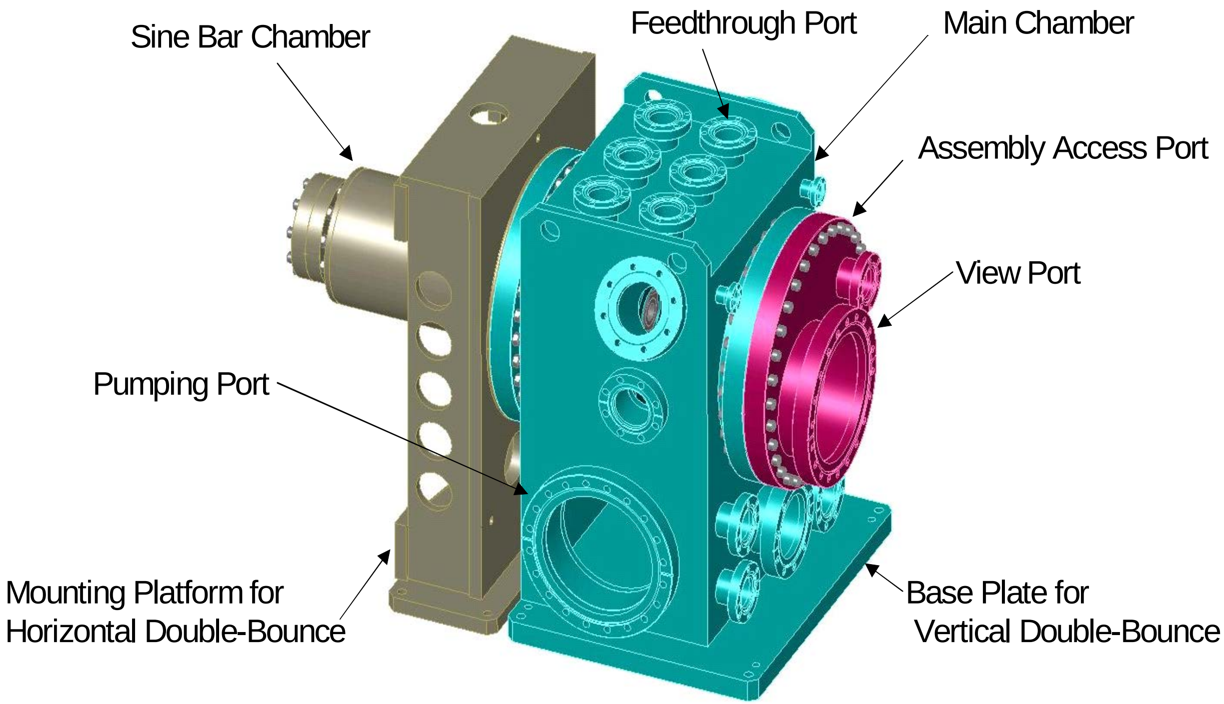
A numbers of linear stages have been developed at the APS as the basic functional modules for the various supporting applications.

- Commercial cross-roller bearings and stepping motor driving system are used in most of the stages.
- Spring loaded linear potentiometers with 10-μm repeatability have been applied as absolute position sensors for all of the modules.
- For most of the heavy-load stages, a 200-μrad/25-mm straightness of trajectory has been achieved.
- For medium-load stages such as T2-24 vertical stage, a 10-μrad/5-mm straightness of trajectory was demonstrated in the test [1,2,3].

S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
D. Shu et al., proceedings of SPIE Vol. 6665, 66650O1-8 (2007)

UHV ACCM for x-ray double crystal monochromators

Vacuum Chamber



The vacuum chamber for the 8-ID-I new monochromator consists of three major sub-assemblies: a main chamber, a sine bar chamber, and a flange for the monochromator's assembly access with view port. The main chamber has a base mounting plate for the monochromator's vertical double-bounce operation configuration. On the sine bar chamber, there is another mounting platform, which is perpendicular to the main chamber base plate, for the monochromator's horizontal double-bounce operation configuration.

S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
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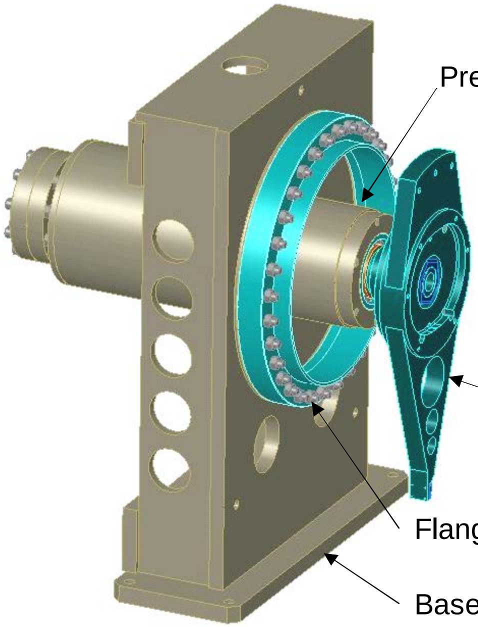
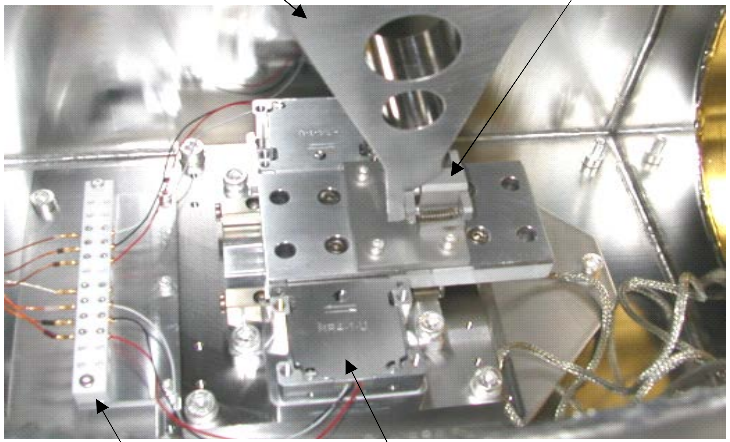
UHV ACCM for x-ray double crystal monochromators

Main Sine Bar Structure and Driver





The main sine bar is assembled at the end of a precision hollow shaft supported by three sets of UHV-compatible precision bearings inside a precisely machined rigid housing, which permits stable angular rotation of the crystal optics. Using a ruby sapphire ball as a precision contact point, the sine bar arm is driven by a commercial ceramic-motor-driven linear stage [7-10] which has 0.01 micron linear positional resolution, yielding high angular resolution of the sine bar mechanism.

S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
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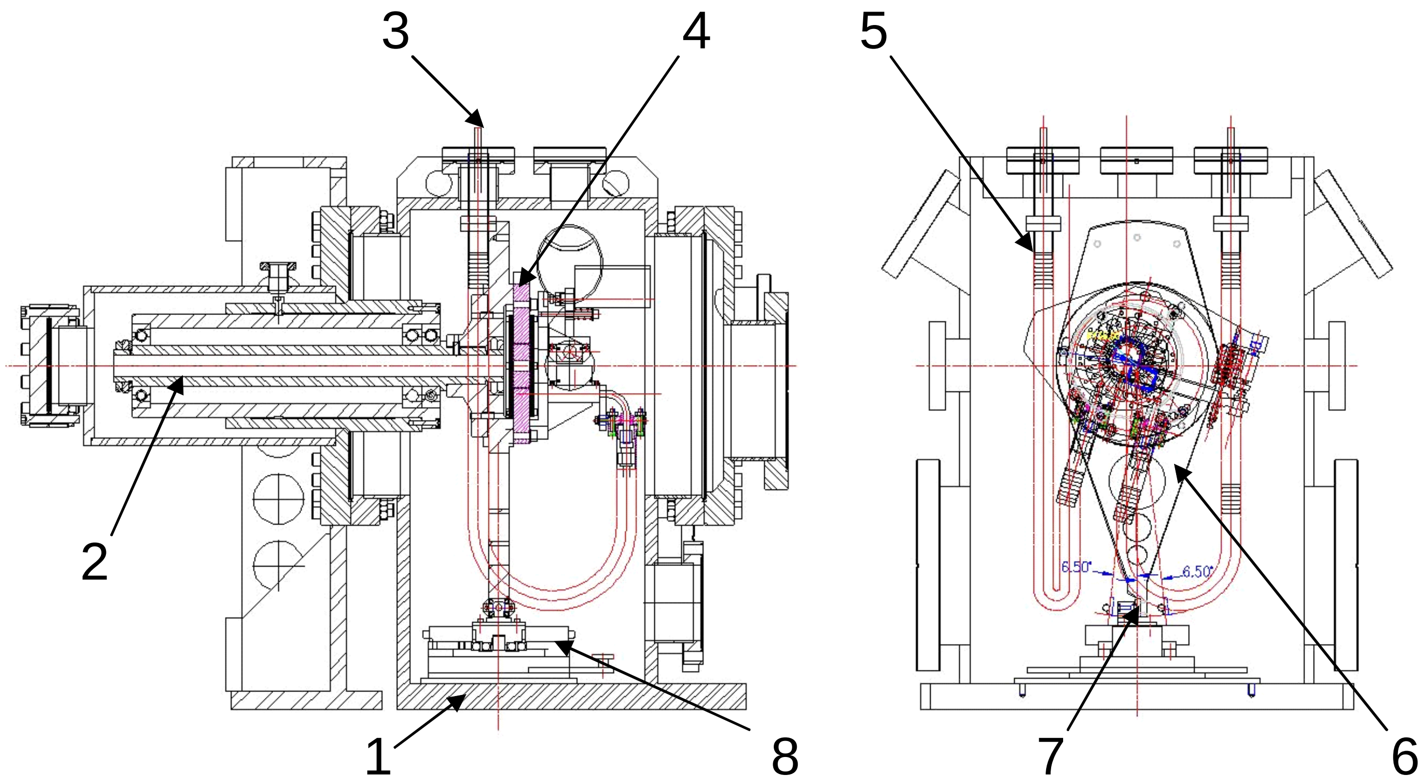
UHV ACCM for x-ray double crystal monochromators

Main Sine Bar Structure and Driver



Detailed cross-sectional side and front views showing the mechanical and vacuum design of the artificial channel cut monochromator. In the center and right panels the "pink" x-ray beam is incident from the right and the monochromatic beam is transmitted to the left.

S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
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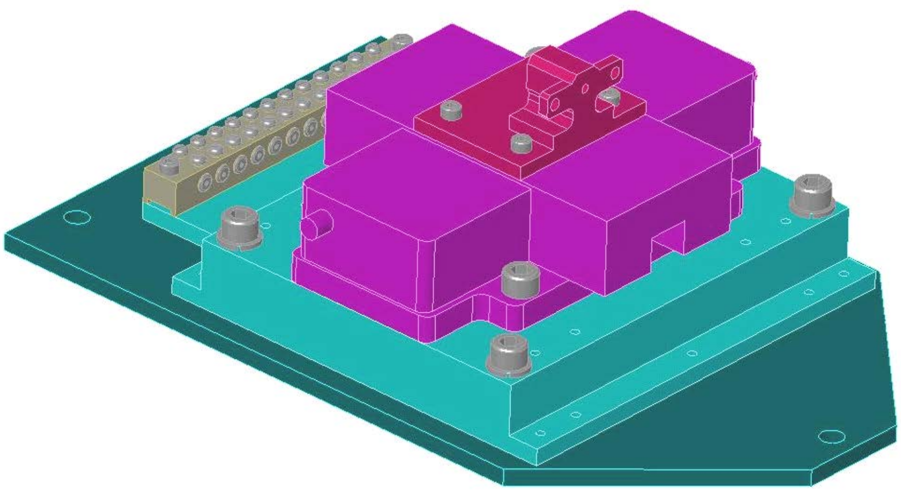
UHV ACCM for x-ray double crystal monochromators

Main Sine Bar Structure and Driver

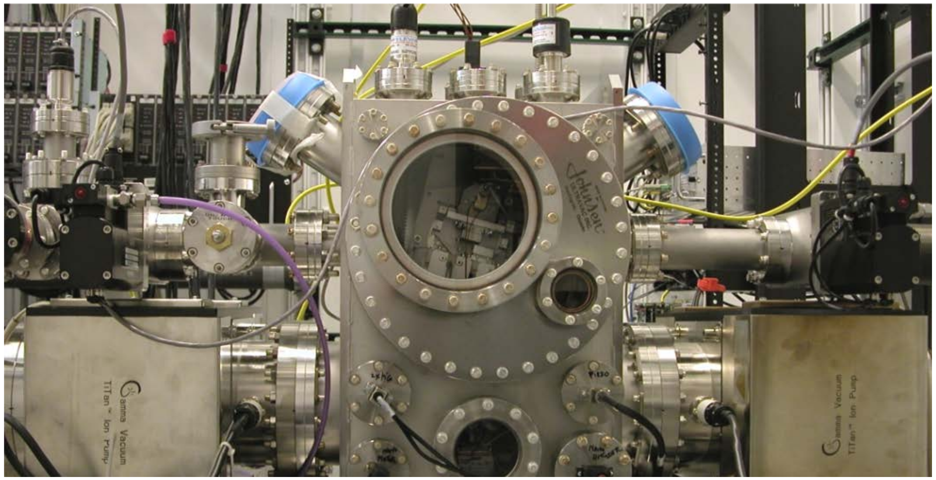


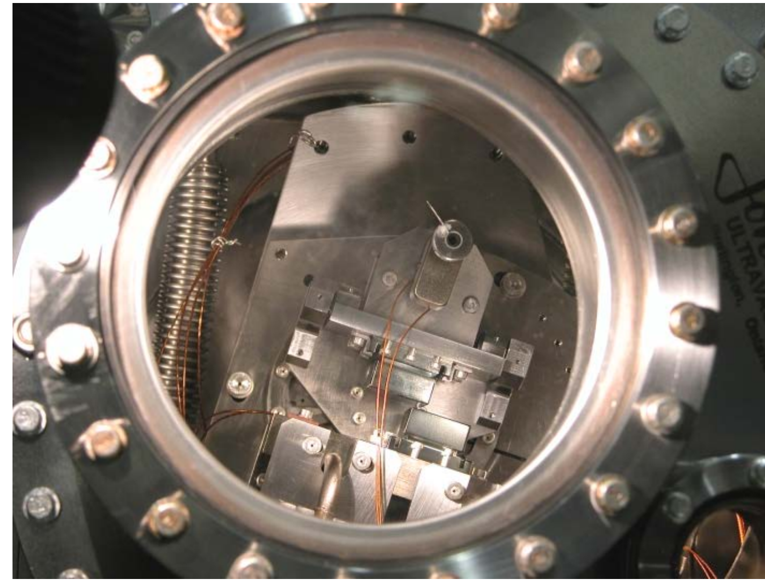
The main sine bar driver is an UHV-compatible linear slide assembly comprised of a precision slide from Alio Industries™, ceramic-motors from Nanomotion™, an encoder from Renishaw™, and an ACS Motion™ SPiiPlus stand-alone Ethernet servo controller. The combination delivers exceptionally precise closed-loop positioning in vacuum over extended length scales and velocity ranges.

S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
D. Shu et al., proceedings of SPIE Vol. 6665, 66650O1-8 (2007)

UHV ACCM for x-ray double crystal monochromators

Water-cooling system

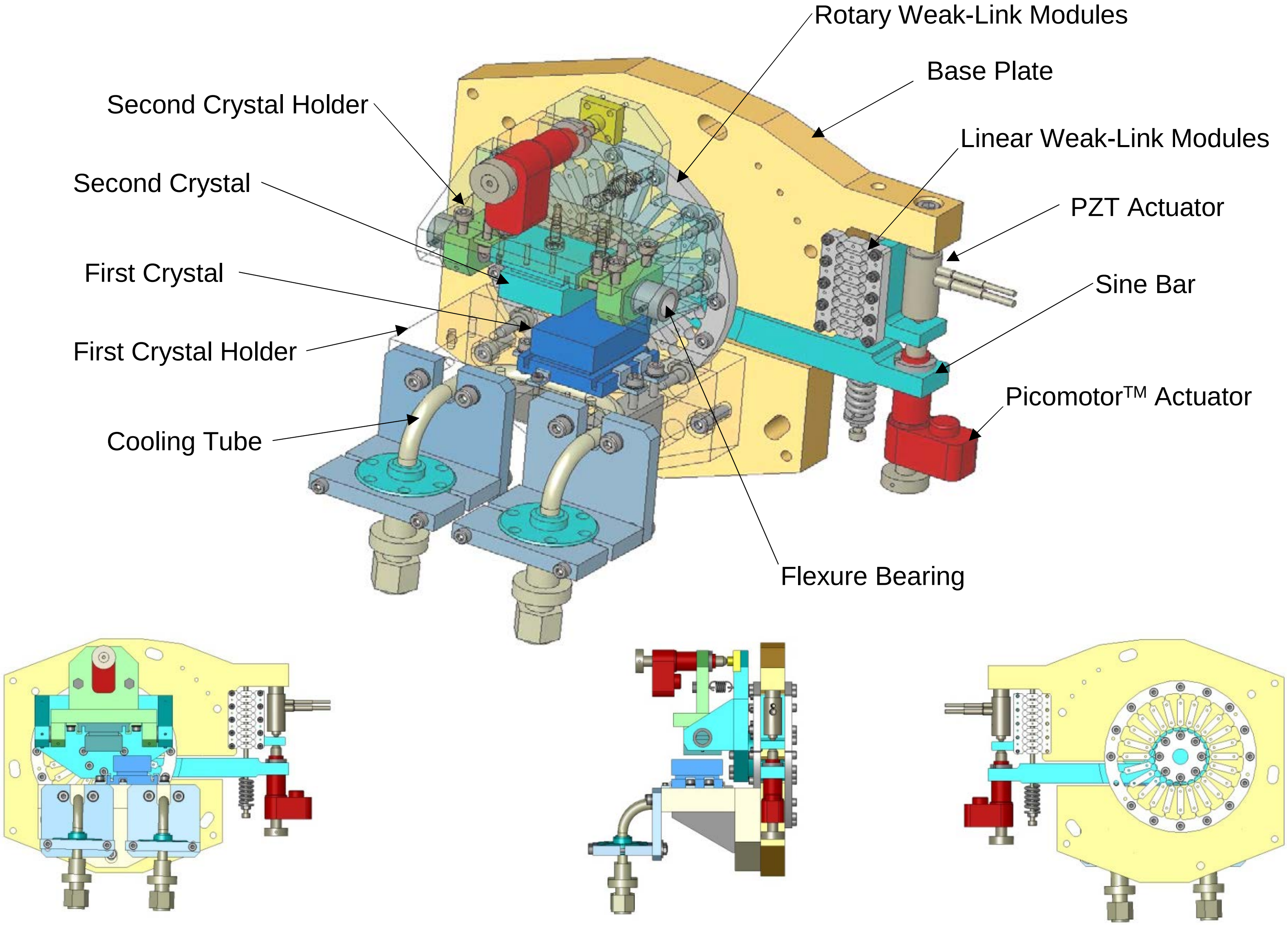




The artificial channel-cut crystal mechanism (ACCM) developed for the new 8-ID-I monochromator is the first such mechanism with UHV compatibility. Many mechanical details in this mechanism are carefully modified for UHV compatibility, such as using UHV-compatible materials and vented fasteners, prevention structures with locked gas packet, etc. As shown in Fig. 6, water cooling is provided for the first crystal by radiation resistant flexible cooling tubes shrouded by a vacuum bellows used in reverse pressure. With this style of water connection, the direct vacuum-to-water junction is avoided, eliminating the risk of water leak damaging the UHV environment.

S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
D. Shu et al., proceedings of SPIE Vol. 6665, 66650O1-8 (2007)

UHV-Compatible Artificial Channel-Cut Crystal Mechanism



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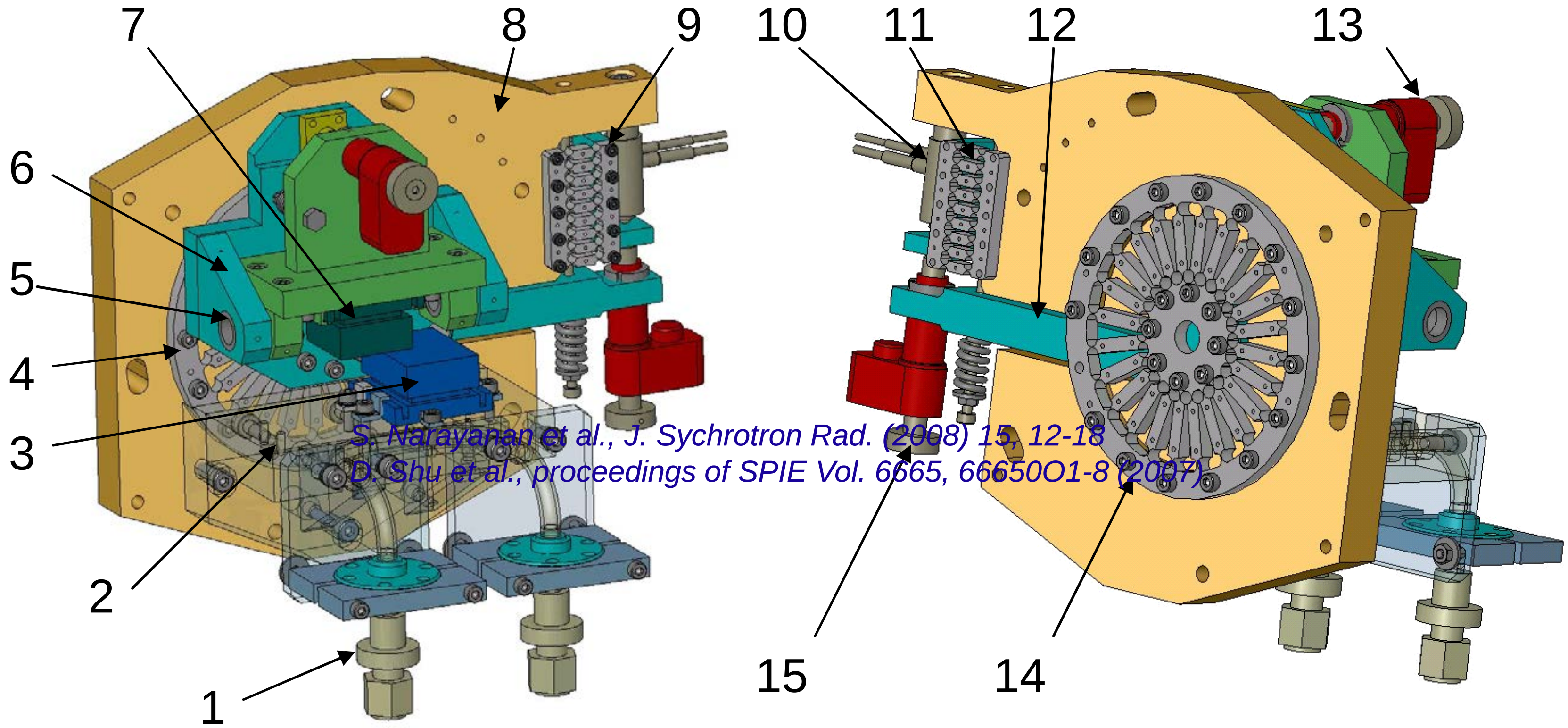
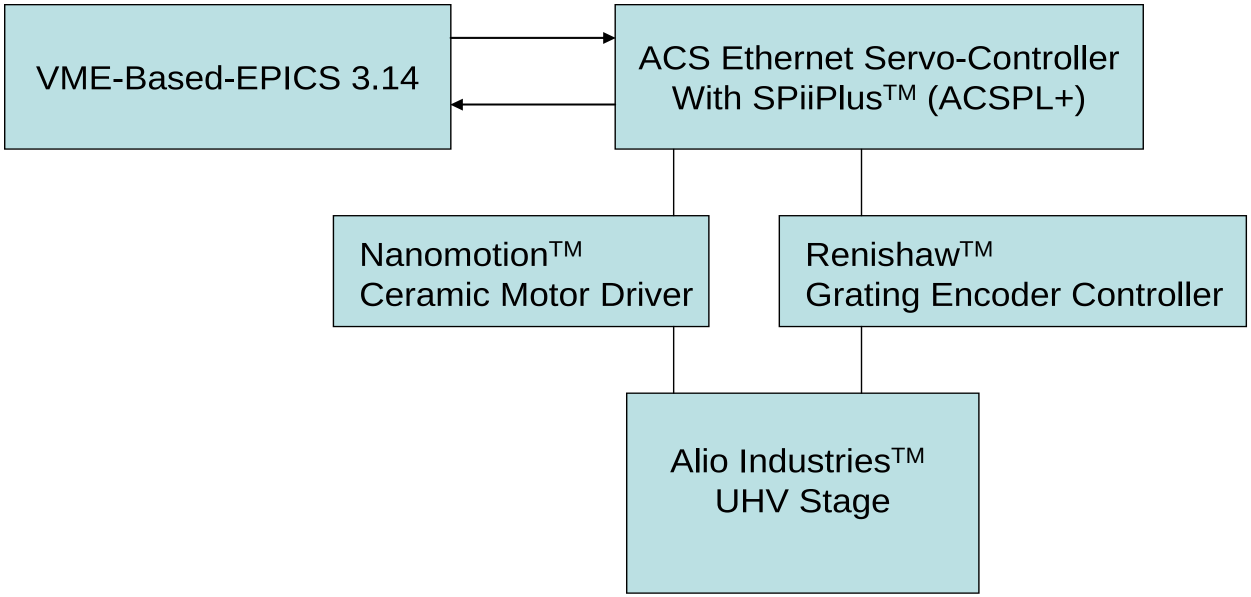
UHV-Compatible Artificial Channel-Cut Crystal Mechanism



Front side and back side views of a 3-D model for a typical high-stiffness weak-link mechanism for an "artificial channel-cut crystal". (1) Cooling tube; (2) First crystal holder; (3) First crystal; (4) and (14) Rotary weak-link modules; (5) flexure bearing; (6) Second crystal holder; (7) Second crystal; (8) Base plate; (9) and (11) linear weak-link modules; (10) PZT actuator; (12) Sine bar: (13) and (15) PicomotorTM actuators. [9]

S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
D. Shu et al., proceedings of SPIE Vol. 6665, 66650O1-8 (2007)

UHV ACCM for x-ray double crystal monochromators



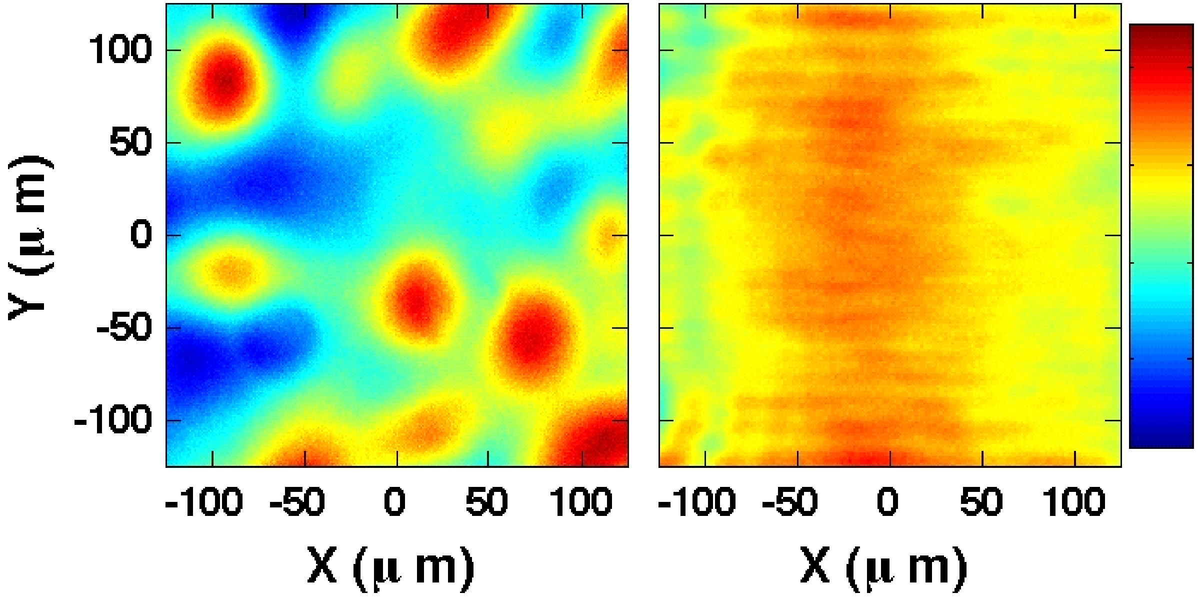
The new monochromator uses a customized UHV-compatible linear stage assembly to drive the main sine bar. It consists of a precision stage from Alio Industries™, piezoelectric actuators from Nanomotion™, an encoder from Renishaw™, and an ACS Motion™ SPiiPlus standalone Ethernet servo-controller. The combination delivers exceptionally precise closed-loop positioning in vacuum over extended length scales and velocity ranges. Since this new monochromator is an integral part of the APS 8-ID-I x-ray beamline instrument, it is important that this new assembly could be seamlessly integrated into APS beamline 8-ID's VME-based-EPICS control system.

S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
D. Shu et al., proceedings of SPIE Vol. 6665, 66650O1-8 (2007)

UHV ACCM for x-ray double crystal monochromators

Test results of the UHV X-ray Monochromator for XPCS at the APS 8-ID

This new monochromator was installed in the APS beamline 8-ID-I in April 2006. Evidently, its transverse intensity profile is considerably more uniform than that produced by the traditional channel-cut monochromator previously installed in beamline 8-ID-I (left side of the figure). In particular, the variance of the recorded intensities in the center range |X| and |Y| < 67 microns is 50% less in the right side of the figure as compared with that in the left side of the figure.



S. Narayanan et al., J. Sychrotron Rad. (2008) 15, 12-18
D. Shu et al., proceedings of SPIE Vol. 6665, 66650O1-8 (2007)

UHV ACCM for x-ray double crystal monochromators

Design of the UHV X-ray Monochromator for high pressure x-ray studies with diamond anvil cells at the APS HP-CAT 16-BM

HPCAT HIGH PRESSURE COLLABORATIVE ACCESS TEAM
at the Advanced Photon Source
GEOPHYSICAL LABORATORY, Carnegie Institution of Washington

- A wide variety of materials covering almost the entire periodic table have been used for high pressure study, which requires a wide x-ray energy monochromator at beamlines for different x-ray techniques, such as x-ray diffraction/scattering, spectroscopy, and imaging.

- The bending magnet radiation has wide energy spectrum with constant and smooth flux distribution. It is ideal for many applications to make measurements with wide energy range.

- An artificial channel-cut monochromator has been commissioned and is operational at APS HPCAT bending magnet beamline since 2008.

- The fixed vertical slits provide an exit beam at constant height when energy is scanned, which enables novel high pressure x-ray studies with diamond anvil cells.

W. Yang et al., proceedings of SRI-2008, Saskatoon, Canada, June 10-13 2008

UHV ACCM for x-ray double crystal monochromators

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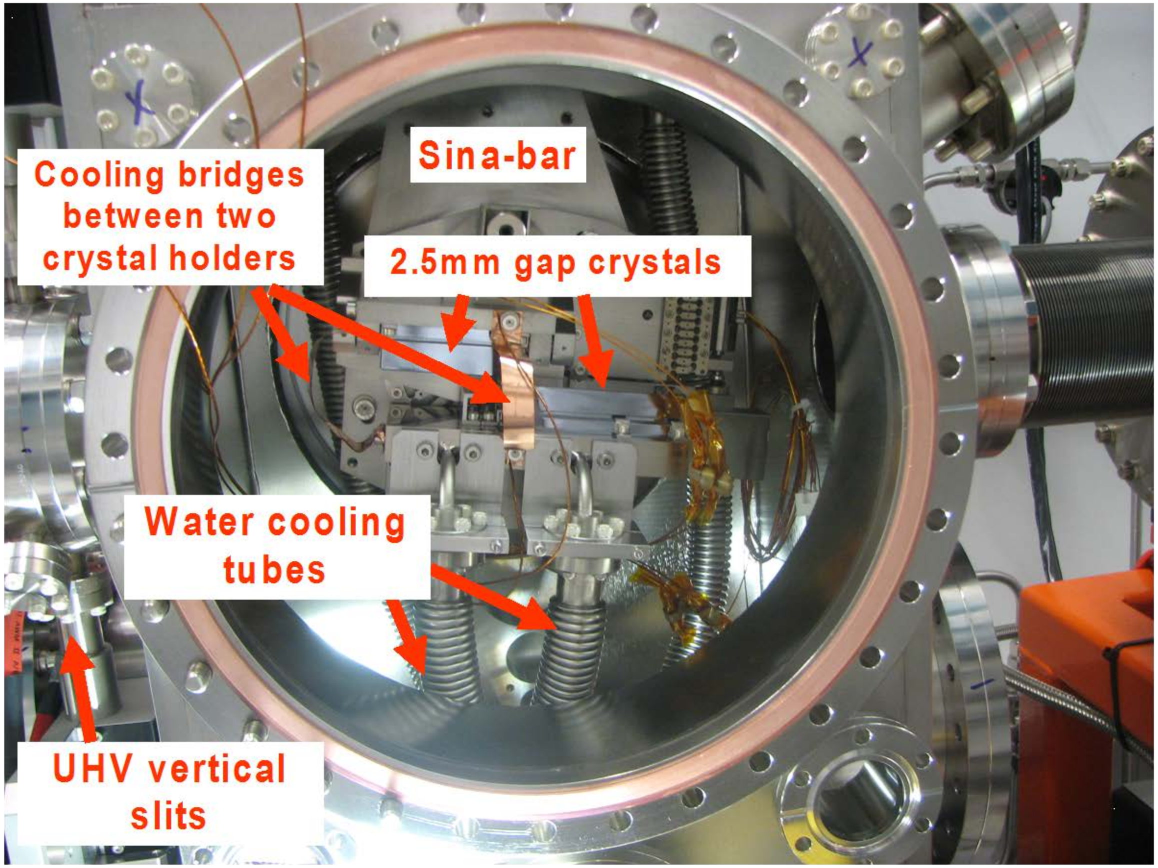

A UHV compatible high precision (10 nm) nanomotor (Nanomotion™) with long travel range (100 mm) is used to drive a 232 mm long sin-bar arm, which gives 40 nrad angular resolution and 24 degrees of total Bragg angle range. This angular range covers Si (111) reflection energy from 5 keV to 70 keV.

W. Yang et al., proceedings of SRI-2008, Saskatoon, Canada, June 10-13 2008

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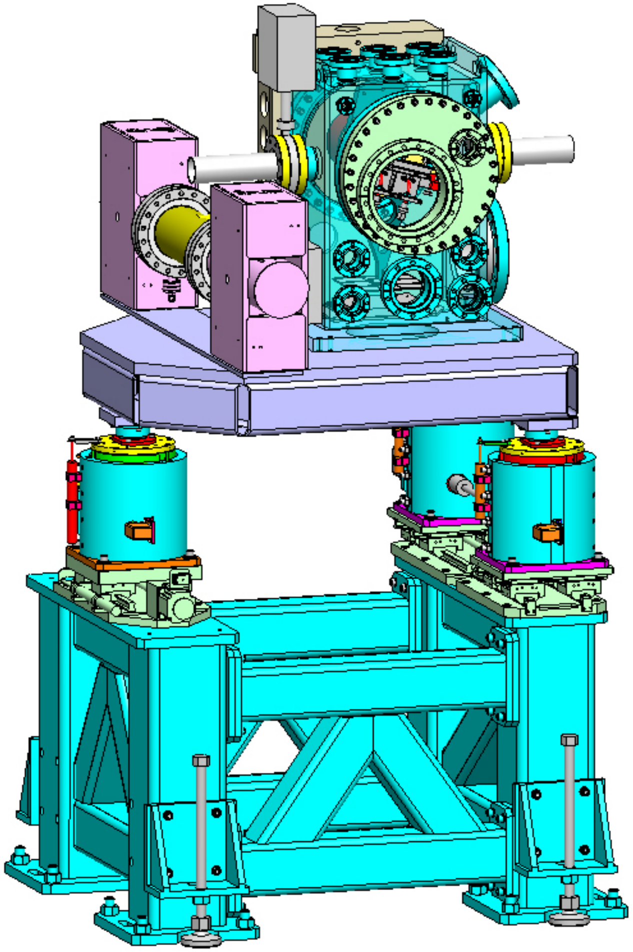

- A 5-D supporting table for first crystal alignment.

W. Yang et al., proceedings of SRI-2008, Saskatoon, Canada, June 10-13 2008

UHV ACCM for x-ray double crystal monochromators

Design of the UHV X-ray Monochromator for high pressure x-ray studies with diamond anvil cells at the APS HP-CAT 16-BM

- Both crystals are cut from the same Si (111) ingot. Fine tuning of second crystal is performed with ACCM mechanism. The ultimate aligning resolution for pitch and roll is 4nm (30 nrad) and 40 nm (300 nrad), respectively.

- A small gap of 2.5 mm was chosen for this monochromator with maximum 2 mm vertical acceptance of incident beam. Over the entire energy range, the exit beam height moves within ±140 microns. In order to fix the monochromatic beam height for the downstream optics, a pair of UHV compatible high precision vertical slits is installed after the second crystal with a narrower size to keep the exit beam position constant. This ensures the focused beam position after K-B mirrors at the same sample location, which is critical for high pressure study with diamond anvil cells.

- The ACCM mechanism ensures the two crystals have a fixed relative geometry. Once they are aligned, there will be no more tuning required between two crystals. High flexible stainless-steel formed bellows are used for water cooling system on the first crystal.

- A RTE-17 type chiller (ThermoFisher Scientific) is used for constant temperature water supply. Two copper belts are used to connect the two crystal holders to remove the heat load from second crystal, thus shorten the warm-up time.

W. Yang et al., proceedings of SRI-2008, Saskatoon, Canada, June 10-13 2008

UHV ACCM for x-ray double crystal monochromators

Operation status of the UHV X-ray Monochromator for high pressure x-ray studies with diamond anvil cells at the APS HP-CAT 16-BM

An e-mail from HP-CAT beamline scientist (Dr. Wenge Yang) on April 17, 2014:

- *The artificial channel cut monochromator at 16-BM-D has been working very well. We are able to do spectroscopy scan over wide energy range.*

- *After initial alignment of the second crystal (both theta and chi direction), we do not need to adjust these two motors for wide enegy range we usually use (5-40 keV). I attach one figure with the entire spectrum scan with energy 5-70 keV and second figure for the energy calibration for energy 5 keV to 40 keV. For both work, we do not need to retune the second crystal angles.*

- *We have replaced the nanomotion stage with a high resolution stepping motor stage with encoder on it. The energy resolution is good enough. We are using Si (111) crystal with stepping motor travel range 100 mm. So we can have energy range from 5keV to beyond 70 keV for the BM beamline.*

W. Yang et al., proceedings of SRI-2008, Saskatoon, Canada, June 10-13 2008

UHV ACCM for x-ray double crystal monochromators

Design of the UHV X-ray Monochromator for high pressure x-ray studies with diamond anvil cells at the APS HP-CAT 16-BM

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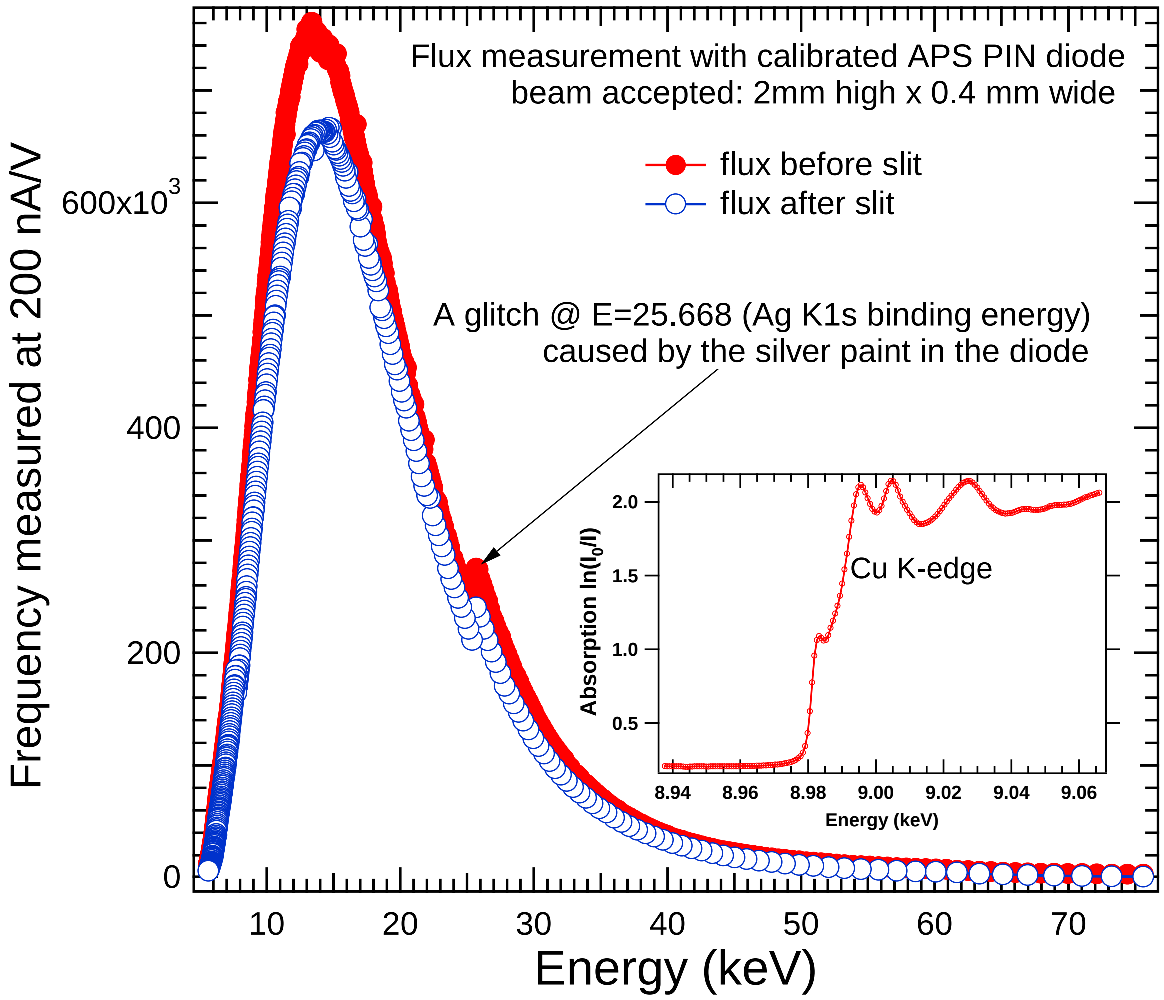

Fig. 2 The intensity measurement over entire energy range. The energy was calibrated based on 16 XANES characteristic peak energies like one as insert from fine energy scan near Cu edge.

W. Yang et al., proceedings of SRI-2008, Saskatoon, Canada, June 10-13 2008

UHV ACCM for x-ray double crystal monochromators

Design of the UHV X-ray Monochromator for high pressure x-ray studies with diamond anvil cells at the APS HP-CAT 16-BM

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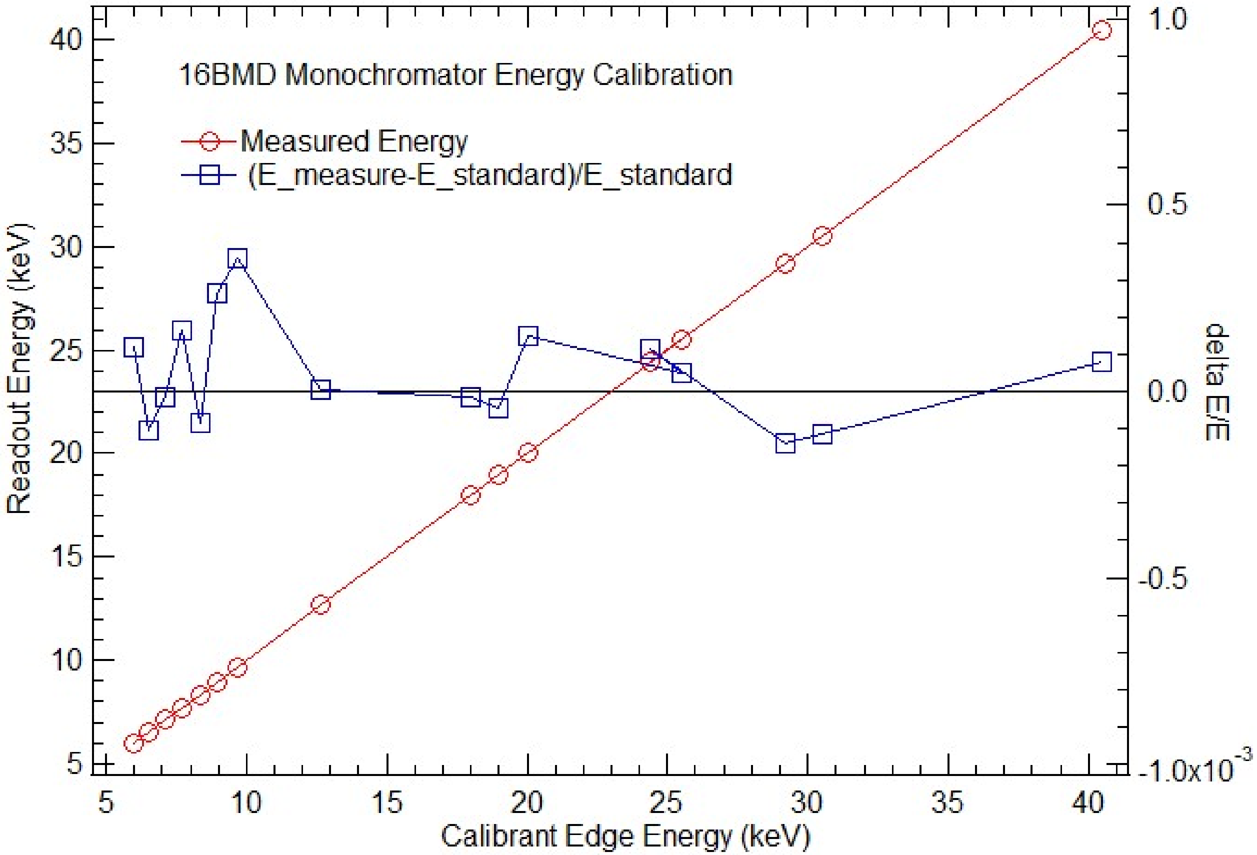
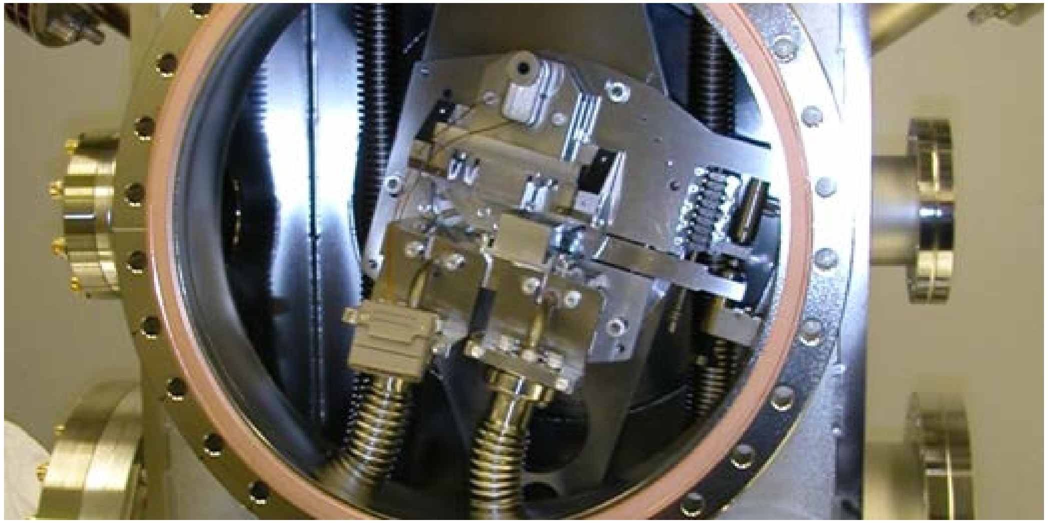


W. Yang et al., proceedings of SRI-2008, Saskatoon, Canada, June 10-13 2008

UHV ACCM for x-ray double crystal monochromators at LCLS/SLAC



A photograph of the UHV x-ray crystal monochromator at the APS 8-ID-I.

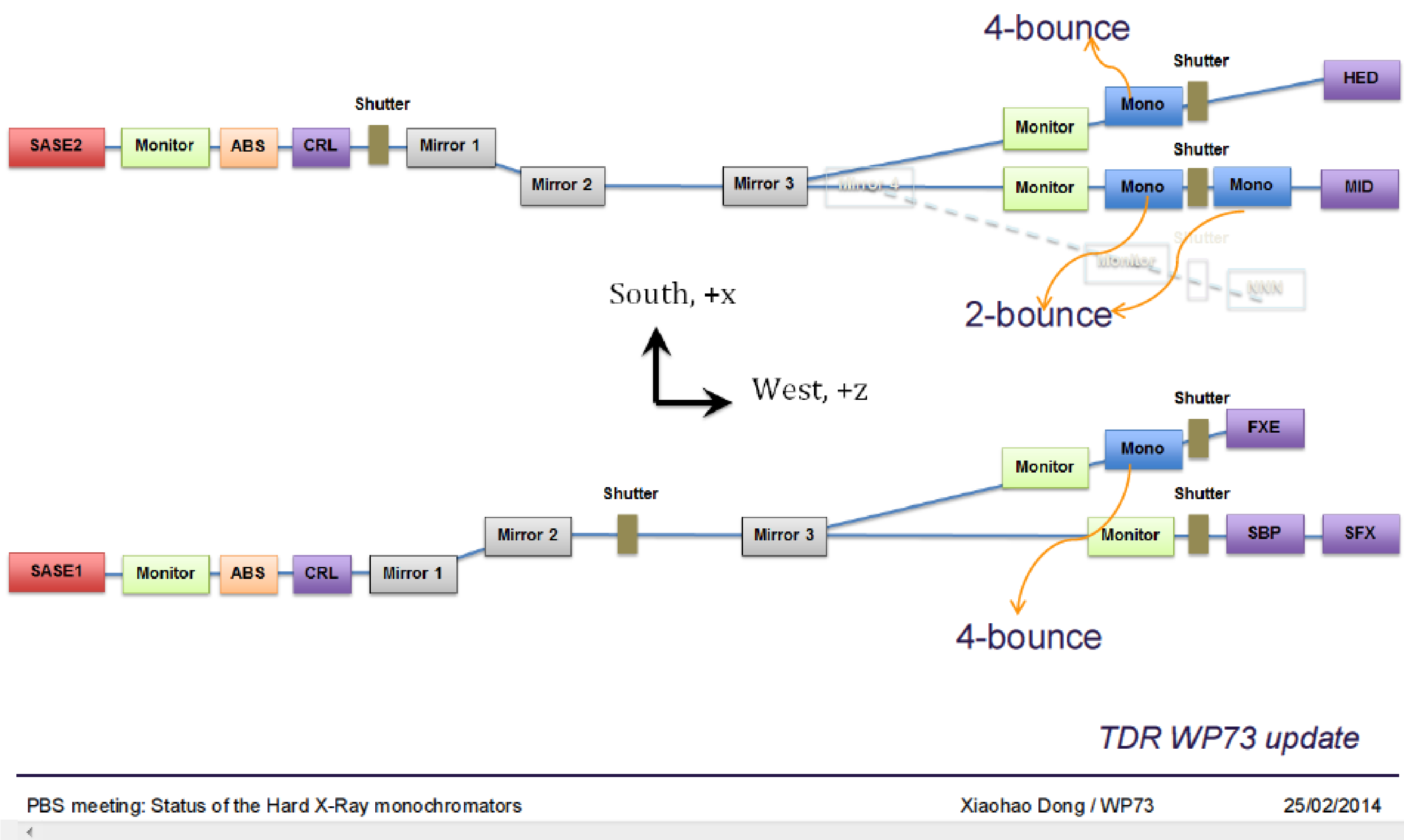
- Two APS-designed ultra-high-vacuum (UHV)-compatible, water-cooled, artificial channel-cut crystal monochromators for x-ray photon correlation spectroscopy (XPCS) and other applications were constructed and installed at the Linac Coherent Light Source (LCLS) at the SLAC National Accelerator Laboratory.
- The first such monochromator was commissioned and characterized on August 27, 2010.

- The monochromator was originally developed by APS scientists and engineers to meet the challenging stability and optical requirements of the XPCS program at XSD) beamline 8-IDI at the APS.
- Using a laminar structure configured and manufactured by chemical etching and lithography techniques, a planar-shape, high-stiffness, high-precision weak-link module was designed and built.
- The precision and stability of this mechanism allowed for alignment or adjustment of an assembly of crystals to achieve the same performance as does a single channel-cut crystal, so the device was called an “artificial channel-cut crystal.”
- A similar monochromator has also been constructed for the HP-CAT beamline 16-Bm at the APS for high-pressure research.

D. Shu et al., APS Science 2010, p134, ANL-10/35, ISSN 1931-5007 (2011)

UHV ACCM for x-ray double crystal monochromators at EXFEL

Argonne Work For Others (WFO) project 857Y2 with EXFEL
for Cryo-cooling UHV ACCM design collaboration

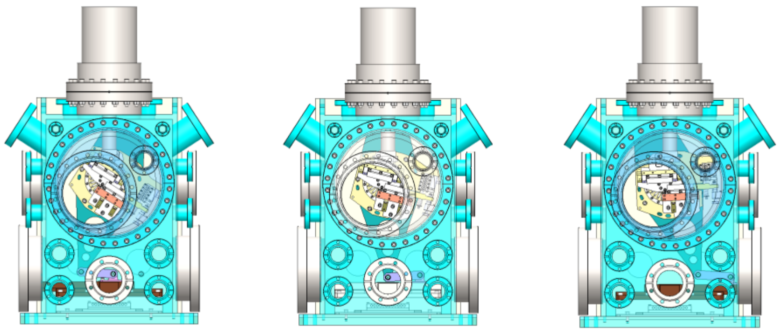


Courtesy of X. Dong and H. Sinn, EXFEL

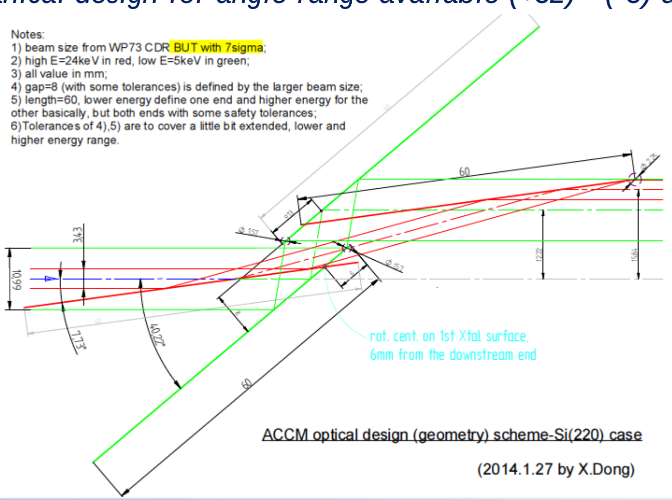
UHV ACCM for x-ray double crystal monochromators at EXFEL

Argonne Work For Others (WFO) project 857Y2 with EXFEL
for Cryo-cooling UHV ACCM design collaboration

Option for Si(111)   Energy range: 5 – 25 KeV
Bragg angle: 23.3 – 4.72 deg.
Mechanical design for angle range available (+32) – (-3) deg

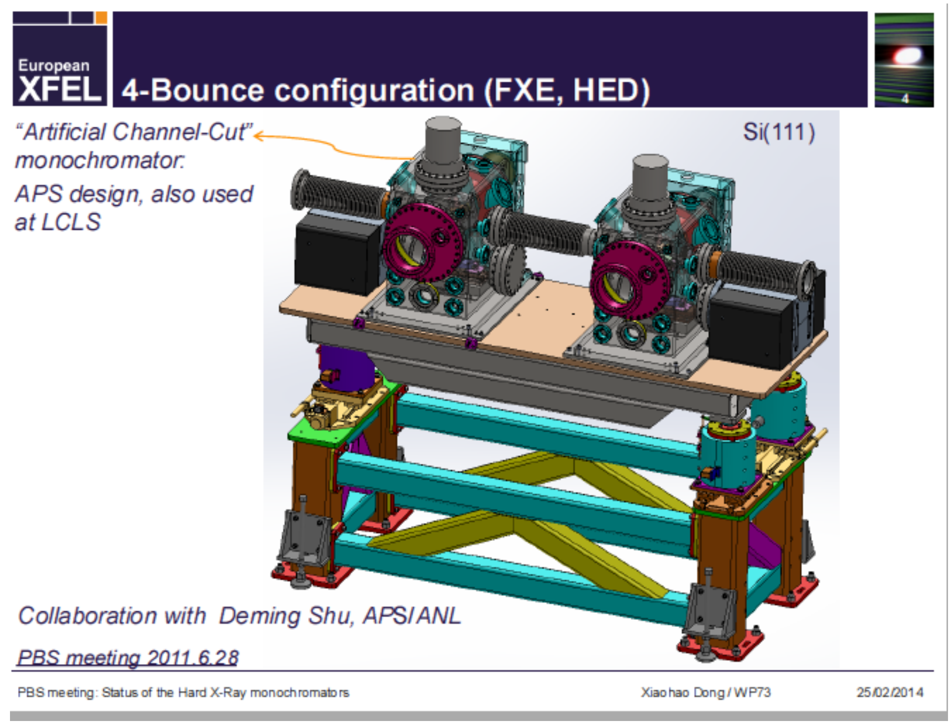


Option for Si(220)   Energy range: 5 – 25 KeV
Bragg angle: 40.5 – 7.5 deg
Mechanical design for angle range available (+32) – (-3) deg



ACCM optical design (geometry) scheme-Si(220) case

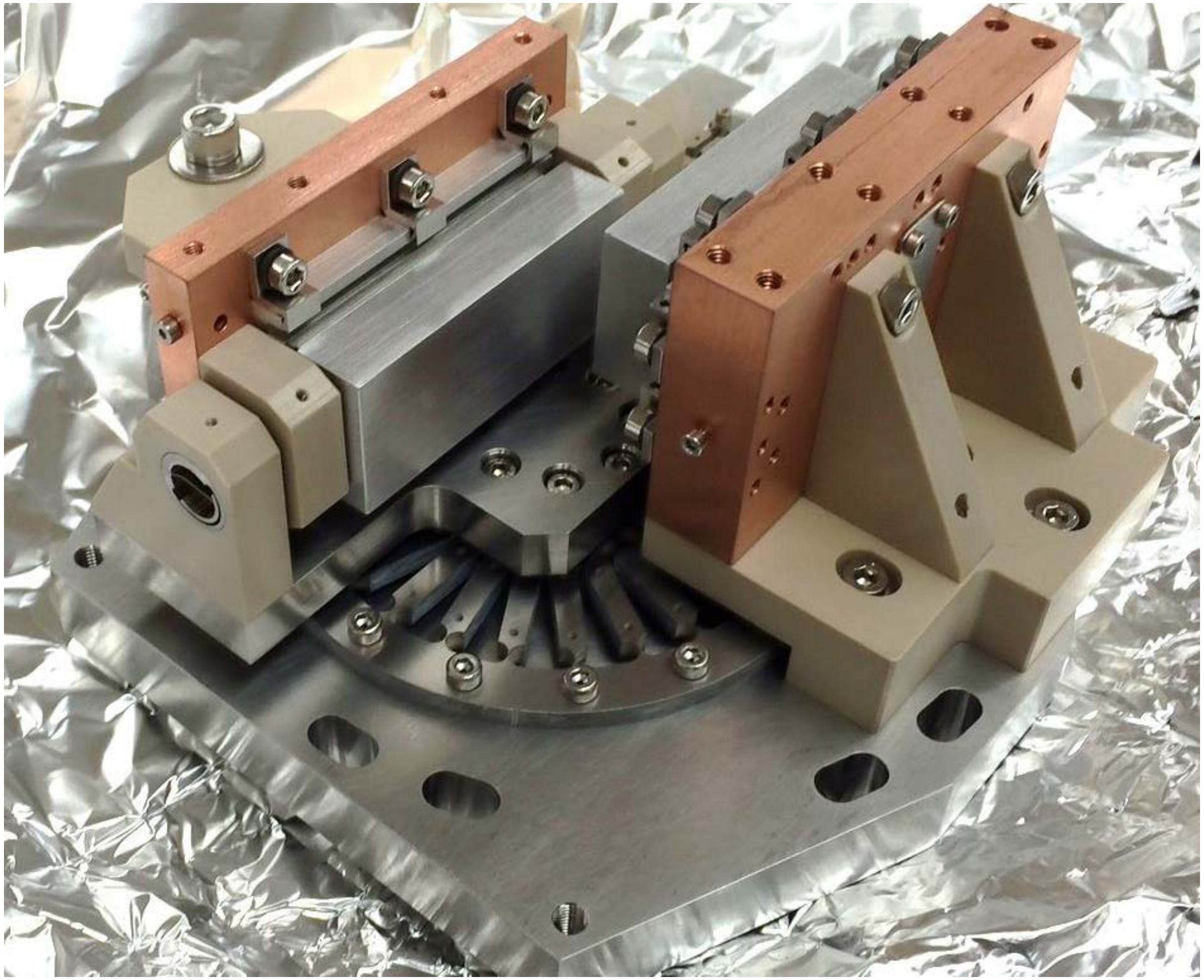
(2014.1.27 by X.Dong)



Courtesy of X. Dong and H. Sinn, EXFEL

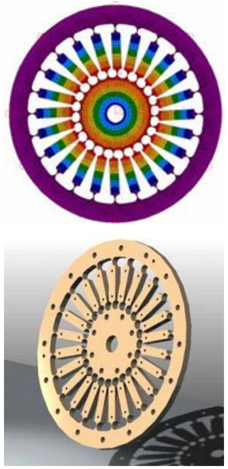
UHV ACCM for x-ray double crystal monochromators at EXFEL

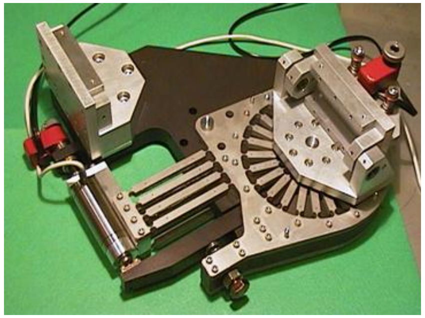
EXFEL received first UHV ACCM manufactured by A.J.R. Industrials, Inc. USA

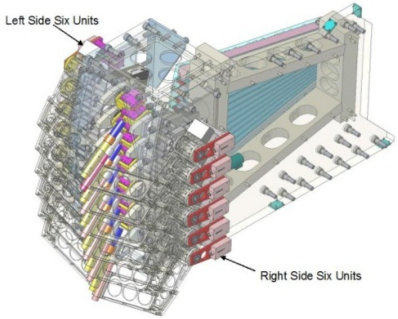


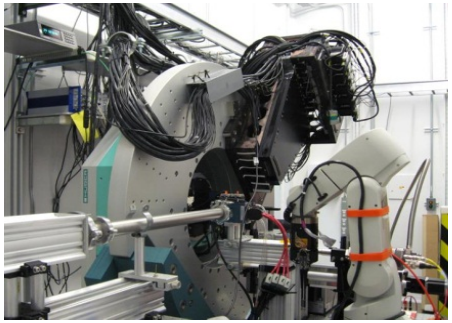
Courtesy of A.J.R. Industrials, Inc.

Summary
Applications of the weak-link-based high precision mechanisms at the APS

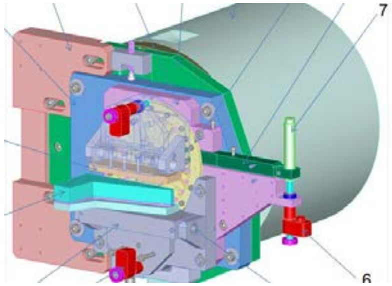




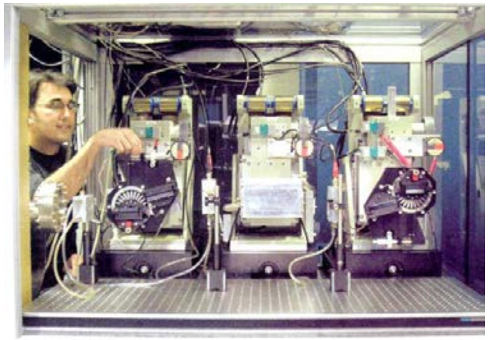




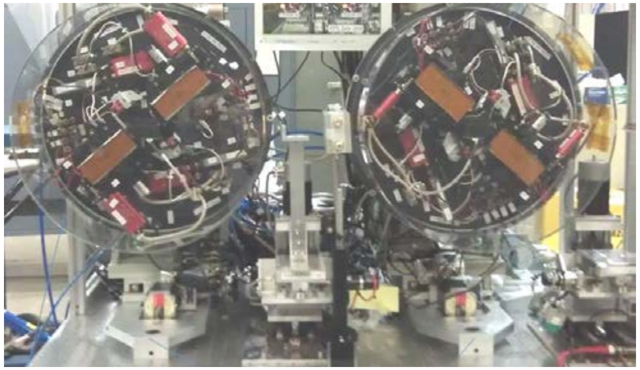
Twelve-analyzer detector system for high-resolution powder diffraction (11-BM)



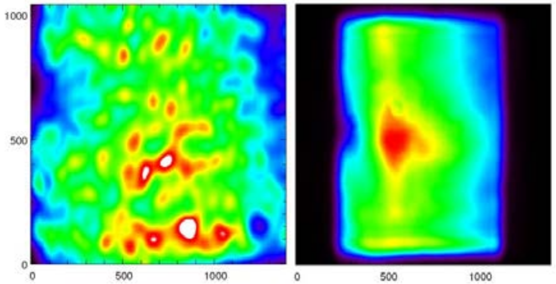
A 3D model of the 15-ID artificial channel-cut crystal stage for the APS USAXS instrument crystal analyzer system :



High-energy-resolution hard x-ray monochromators (3-ID)



CDFDW prototype (30-ID)



UHV-compatible artificial channel-cut crystal monochromator for XPCS (8-ID)

Summary

Flexural stages design for crystal monochromators and analysers at the Advanced Photon Source

- *High-energy-resolution hard x-ray monochromators (3-ID)*
- *HERIX and MERIX monochromators (30-ID)*
- *UHV-compatible artificial channel-cut crystal monochromator for XPCS (8-ID)*
- *UHV-compatible artificial channel-cut crystal monochromator (16-BM)*
- *UHV-compatible artificial channel-cut crystal monochromator for XPCS (LCLS/SLAC)*
- *Four-crystal high-energy high-resolution x-ray monochromator (1-ID)*
- *Twelve-analyzer detector system for high-resolution powder diffraction (11-BM)*
- *Artificial channel-cut crystal stage for a Bonse-Hart USAXS Instrument (15-ID)*
- *Twelve-analyzer detector system for high-resolution powder diffraction (11-BM)*
- *Multi-axis precision flexure stage system for x-ray stereo imaging instrument for particle tracking velocimetry (PTV) (32-ID)*

Spectroscopy applications at APS HP-CAT 16-BM and EXFEL FXE

** A.J.R. Industrials, Inc. had a license from Argonne to commercialize the weak-link nanopositioning stages worldwide. (http://www.ajrindustries.com)*

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[12] H. Sinn et al., TDR X-ray Optics and Beam Transport, XFEL.EU TR-2012-006 (2012)

Thanks for Your Attention