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Development of Ultra-High Energy Resolution Monochromator/ Analyzer meV Prototype System

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Abstract

In this paper ADC will discuss the design and development of Ultra-High Energy Resolution Monochromator/ Analyzer meV Prototype System for Brookhaven National Lab NSLS II Inelastic X-ray Scattering (IXS) project beamline. The research and development effort conducted by IXS beamline is to investigate and develop the optical scheme for an Ultra-high energy resolution monochromator/analyzer of the CDW-CDDW type[1].

Each monochromator and analyzer consists of one collimation and wavelength ("C/W") selection silicon crystal and two dispersion ("D") silicon crystals. The configuration also includes a collimating mirror to collect photons from the sample to be directed into the analyzer.

Figure 1: Monochromator/ Analyzer meV Prototype System

OVERVIEW

This Ultra-High Energy Resolution Monochromator/ Analyzer meV Prototype System was built for use with the National Synchrotron Light Source II (NSLS II) Inelastic X-ray Scattering (IXS) project beamline Research and Development (R&D) effort at Brookhaven National Laboratory.

The system is comprised of a support table, two dual-axis high-precision goniometers, a single-axis inclined goniometer, and five fixed-height spacers. This prototype provides modular motion stages which allow for reconfiguration of the system throughout the IXS optics R&D development effort. A control cabinet with 32 stepper drivers with interface to a Prodex motion controller was provided.

SUPPORT TABLE

The principal function of the support table is to provide a supportive surface for the goniometers of the optics. The base welded steel and has kinematic feet for motions in the X, Y and Z directions. The table surface is composed of granite with tapped holes for affixing the linear guide rails to move the XZ carriers, Figure 2.

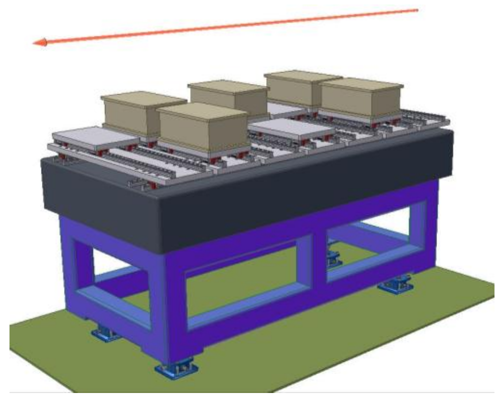

Figure 2: Support table with XZ carriers

Table 1: Support table parameters

Working surface (top) size	2000 mm L X 1000 mm W
Rotation adjustment range	± 0.5 degrees
Height adjustment range	± 20 mm
XZ carriers load capacity	150kg each

DUAL AXIS HIGH PRECISION GONIOMETERS

The primary function of the dual-axis high-precision goniometers, Figure 3 below, is to support the two dispersion crystals of the system.

Figure 3: Dual-axis high precision goniometer

The coaxial goniometers provide motorized translations which are perpendicular to the x-ray beam in the X and Y directions and two independent rotation axes which are coaxial and parallel to the X axis. The rotation axes are at the minimal beam height.

Table 2: Dual-axis high-precision goniometer parameters

X, Y Axes	Range: ±50 mm
	Resolution: 2µm/full step
	Repeatability: 0.5µm
	Actuator: stepping motor
θ_1, θ_2 axes	Range: ±180 degrees manual, ±2 degree min. motorized
	Resolution: 0.005 arcsec/full step
	Axis Wobble: 0.1arcsec/360 degree
	Actuator: stepping motor driven tangent-bar

SINGLE AXIS INCLINED GONIOMETER

The single-axis inclined goniometer supports the mirror and mirror enclosure. The single-axis inclined goniometer, Figure 4, is centered between the two dual-axis high precision goniometers atop the support table.

Figure 4: Single-axis inclined goniometer (CAD & photo)

It delivers motorized translations in both the X and Y directions, perpendicular to the x-ray beam, two rotation axes and two tilt axes.

Table 3: Single-axis inclined goniometer parameters

X, Y axes	Range: ±50 mm
	Resolution: 2µm/full step
	Repeatability: 0.5µm
	Actuator: stepping motor
θ axis	Range: ± 120 degree (minimum)
	Resolution: 0.3 arcsec/full step
	Actuator: stepping motor
Θ, X axes	Range: ±5 degrees
	Resolution: 10µm
	Actuation: manual (micrometer)
X_0, Y_0 axis	Range: ±5 mm
	Resolution: 10µm
	Actuation: manual (micrometer)
Goniometer load	0.5 kg
Distance, center-of-rotation of axes	30 mm (minimum)

TEST REPORTS

The goniometer components were inspected and tested to insure guidelines were met or exceeded. Reports included bearing alignment, minimum travel range requirements, and limit switch accuracy. Repeatability for the components was tested; measured using a Keyence high accuracy optical micrometer. A snapshot of the repeatability charting of a few components can be seen below in Tables 4 and 5.

Table 4: DS500-50 repeatability

Mechanical Test

Measurments taken using the Keyence high accuracy optical micrometer, controlled using the Micro Lynx stepper motor controller in 'open loop' format (no encoder feedback).

Description Text in Yellow	System Serial Number: 051911-01
Entered data in Green	Job number: 12-013
Calculated values in Blue	

Carrier Position Closest to Motor

Blade Position	Actual measured move blade (mm)						Uni-Directional error (mm) (Max-Min)	Bi-Directional error (mm) (Max-Min)
	+ direction 1'st pass	- direction 2'nd pass	+ direction 3'rd pass	- direction 4'th pass	+ direction 5'th pass	- direction 6'th pass		
1		11.312		11.312		11.312	0.000	0.000
2	16.189	16.196	16.189	16.196	16.189	16.196	0.000	0.007
3	21.073	21.079	21.073	21.079	21.073	21.079	0.000	0.006
4	25.957	25.962	25.957	25.962	25.957	25.962	0.000	0.005
5	30.840		30.840		30.840		0.000	0.000
						Largest Positioning Error	0.000	0.007

Carrier Position Center

Blade Position	Actual measured move blade (mm)						Uni-Directional error (mm) (Max-Min)	Bi-Directional error (mm) (Max-Min)
	+ direction 1'st pass	- direction 2'nd pass	+ direction 3'rd pass	- direction 4'th pass	+ direction 5'th pass	- direction 6'th pass		
1		8.345		8.345		8.345	0.000	0.000
2	13.223	13.228	13.223	13.228	13.222	13.228	0.001	0.006
3	18.106	18.112	18.106	18.112	18.106	18.112	0.000	0.006
4	22.990	22.995	22.989	22.995	22.989	22.994	0.001	0.006
5	27.873		27.873		27.873		0.000	0.000
						Largest Positioning Error	0.001	0.006

Carrier Position Furthest From Motor

Blade Position	Actual measured move blade (mm)						Uni-Directional error (mm) (Max-Min)	Bi-Directional error (mm) (Max-Min)
	+ direction 1'st pass	- direction 2'nd pass	+ direction 3'rd pass	- direction 4'th pass	+ direction 5'th pass	- direction 6'th pass		
1		1.942		1.942		1.942	0.000	0.000
2	6.821	6.827	6.821	6.827	6.821	6.827	0.000	0.006
3	11.705	11.710	11.705	11.710	11.705	11.710	0.000	0.005
4	16.590	16.594	16.590	16.594	16.589	16.594	0.001	0.005
5	21.473		21.473		21.473		0.000	0.000
						Largest Positioning Error	0.001	0.006

Table 5: TS90 repeatability

Mechanical Test

Measurments taken using the Keyence high accuracy optical micrometer, controlled using the Micro Lynx stepper motor controller in 'open loop' format (no encoder feedback).

Description Text in Yellow	System Serial Number: XXXXX-XX
Entered data in Green	Job number: 12-013
Calculated values in Blue	

Angle Increment Test

Tilt Position	Actual Measured Tilt (°)						Uni-Directional error (°) (Max-Min)	Bi-Directional error (°) (Max-Min)
	- direction 1'st pass	+ direction 2'nd pass	- direction 3'rd pass	+ direction 4'th pass	- direction 5'th pass	+ direction 6'th pass		
1		0.003		0.002		0.002	0.001	0.001
2	0.463	0.475	0.464	0.475	0.464	0.475	0.001	0.012
3	0.946	0.956	0.946	0.956	0.947	0.956	0.001	0.010
4	1.418	1.432	1.420	1.432	1.420	1.432	0.002	0.014
5	1.901	1.913	1.901	1.913	1.901	1.913	0.000	0.012
6	2.381	2.393	2.381	2.393	2.381	2.393	0.000	0.012
7	2.859		2.859		2.859		0.000	0.000
						Largest Positioning Error	0.002	0.014

REFERENCES

[1] Xian-Rong Huang*, Zhong Zhong, Yong Q. Cai, S. Coburm Development of ultrahigh-resolution inelastic x-ray scattering optics Proc. of SPIE Vol. 7077 70771A-9