MAX IV – MicroMAX DETECTOR STAGE*

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Abstract

The MicroMAX beamline at MAX IV Laboratory will employ two detectors to be used independently and move along the beam depending on the diffraction target resolution, starting close to the sample hanging partially over the sample table. The X-ray beam can be deflected by Kirkpatrick-Baez (KB) mirrors in the horizontal and vertical directions or pass undeflected.

The MAX IV Design office designed a detector stage as an in-house project based on the ALBA table skin concept to switch between the two detectors and accurately position the selected detector, either with or without the KB mirrors.

To achieve stability and precision during translations, a large granite block is used, as well as preloaded linear and radial guides, and preloaded ball screws with stepper motors and, in most cases, a gear box. Flexures are used to allow linear motion's pitch and yaw angles. The various motions are layered so that alignment to the beam axis can be done first, and then sample-to-detector distance can be adjusted independently.

A Finite Element Analysis (FEA) were performed to achieve a stable design and measurements of resonance frequencies on the finalized stage were done to verify it.

INTRODUCTION

The MicroMAX beamline at MAX IV Laboratory is designed for macromolecular crystallography and will employ two detectors: the DECTRIS Eiger 2 X CDTe 9M and the Paul Scherrer Institute (PSI) developed Jungfrau 4M. The X-ray beam can be deflected by Kirkpatrick–Baez (KB) mirrors in the horizontal and vertical directions by 6 mrad, or it can pass undeflected. Beam Conditioning Unit (BCU), Diffractometer and the detector stage are designed to align with the beam. The individual detector should have a variable positioning along the beam path, depending on the target resolution of the diffraction data collection.

SPECIFICATION

The stage shall align the active detector to match either the deflected or undeflected beam following in line with the sample. Translations needs to be performed at a fast enough speed to avoid unnecessary waiting times, this is mainly important for the longitudinal translation that is long and can vary within one experimental setup. The detector stage is designed to accomplish the specifications (Table 1). All motion needs to be motorized. The table shall allow for a passthrough vacuum pipe to be manually placed between the detectors to allow the beam to pass to a second experimental hutch.

Table 1: Specifications

	Vert-ictal	**Horiz-ontal**	**Longi-tudinal**	**Pitch**	**Yaw**
Range	10 mm	382.5 mm	940 mm	±0.5°	±0.5°
Resolution	10 µm	10 µm	100 µm	10 µrad	10 µrad
Repeatability	50 µm	50 µm	100 µm	50 µrad	50 µrad
Resonance frequency f_0	>55 Hz				
RMS displacement	<7.5 µm (<10 % of pixel size)				

DESIGN

Inspired by the ALBA table skin concept design [1] a stage was designed around a grouted granite block. Two opposing steel plates are attached with linear guides for vertical translation. On the top part of the plates a thin neck is milled to create a flexure, allowing pitch by moving the two sides by different amounts. The sides are connected by a horizontal plate stiffened by two longitudinal side plates and a centre beam, together forming the vertical/pitch table. On top the other translations are worked out step by step, first horizontal translation for sideways adjustment and to switch between detectors and passthrough pipe. The horizontal is followed by yaw, using radial linear guides motorized by a linear translation translated into an angle by a flexure and then compensating the offset rotation centre with the horizontal axis (Fig. 1). Finally, the two longitudinal stages move each detector independently (Fig. 2) to find the correct focus and keep the unused detector out of the way in the centre of the table where it has less impact on the resonance frequencies. All translations are done with preloaded linear and radial guides and preloaded ball screws with stepper motors and all except for the motion of the detector along the X-ray beam also use a gear box to increase the resolution.

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*Funded by Novo Nordisk Fonden for the MicroMAX project, grant number NNF17CC0030666
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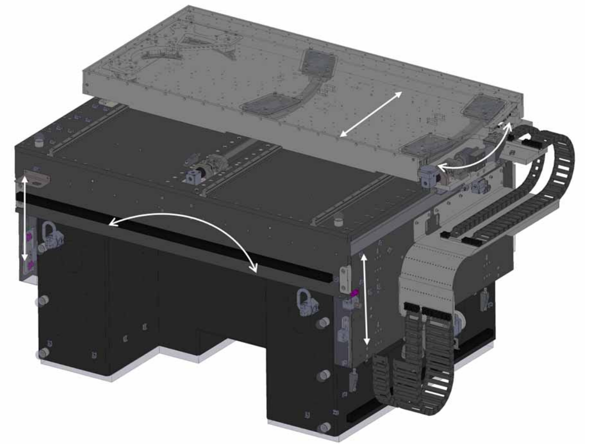

Figure 1: Translations.

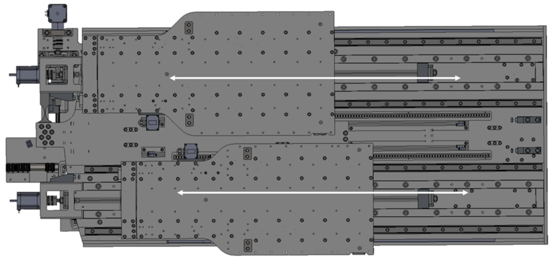

Figure 2: Translations along the beam.

Each flexure neck is specified to handle ±0.5° without having too much negative impact on the resonance frequency. 0.5° pitch causes stress at 192 MPa, giving a comforting safety factor before plastic deformation for the chosen steel (1.2738 / DIN 40CrMnNiMo7) and allowing for some over travel if necessary.

Much effort was put into overall stability of the detector stage, where the overhang of the detectors and the large size of the horizontal plate were the biggest initial concerns. The latter resulting in a stiffening centre beam and the overhang by finding a stiff but weight conservative design of the girders connecting the detector with the linear guides.

The worst cases for stability (Table 2) that can occur during operations is the heaviest detector in the back with the lighter being close to the sample hanging outside the table (Fig. 3) and both detectors sitting together in the detector stage´s centre, acting together (Fig. 4). The complete assembly is shown in Fig. 5.

Table 2: Eigenfrequencies

	Mode 1	**Mode 2**
Detector by sample	60.1 Hz	65. Hz
Detectors centred	63.2 Hz	64.6 Hz

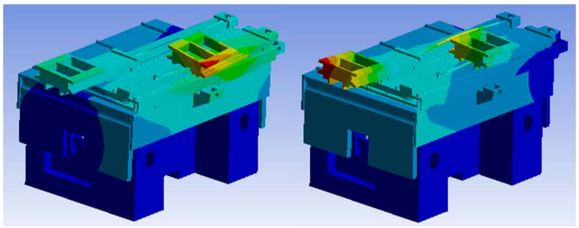

Figure 3: Lighter detector close to sample.

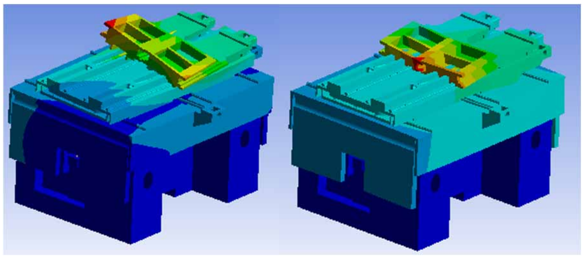

Figure 4: Detectors centred.

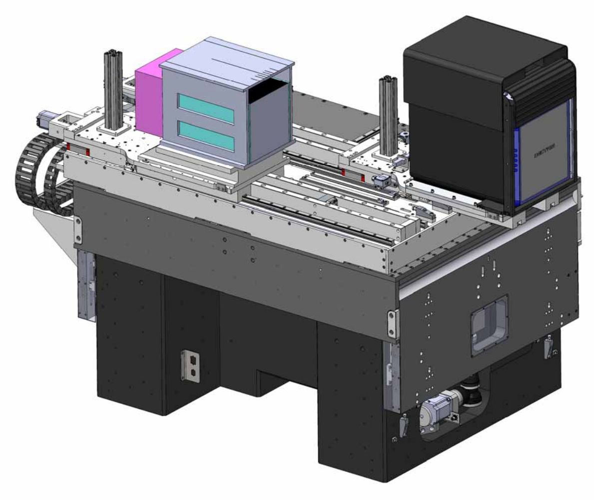

Figure 5: Complete detector stage.

PRODUCTION AND INSTALLATION

The production of mechanical parts was outsourced to a local company and the manufacturing of the granite block together with the assembly of the crucial parts were outsourced to the granite manufacturer that possessed the capability to assemble the main components with precision. Parts not crucial to the main function were later assembled at MAX IV. The stage is temporarily placed on adjustable feet in the experimental hutch, to be grouted later. The final installation, also illustrating some of the electrical routing is shown in Fig. 6.

Figure 6: Installed in the hutch.

MOTION CONTROL

Tests to verify the resolution and repeatability were performed by comparing intended translation with the motor compared to the value shown by the absolute encoders, in open loop and closed loop (Table 3).

Table 3: Motion Tests

	Vert-ictal	**Hori-zontal**	**Longit-udinal**	**Pitch**	**Yaw**
Resolution	0.1 µm	1 µm	1µm	<1 µrad	<1 µrad
Repeatability Closed loop	<1 µm	<3 µm	<3 µm	<3 µrad	<1 µrad
Repeatability Open loop	<5 µm	<7 µm	<7 µm	<5 µrad	<4 µrad
Translations	All axis cover the specified range				

FINAL RESULTS / METEROLOGY TESTS

Measurements of the Root mean square (RMS) displacements on the Eiger2 detector has been performed by the MAX IV Survey, Alignment and Mechanical Stability team. During this test, the detector stage was installed on alignment feet but not grouted and the Jungfrau detector was not installed. The goal was to find the maximum RMS displacements on the Eiger detector and any eigenfrequencies <55 Hz.

The measured RMS displacement at the detector position was below the specified limit of 7.5 µm as shown in Table 4.

Table 4: RMS Displacement

Direction		**Floor**	**Detector**
Horizontal	RMS	3.9 nm	36.8 nm
Vertical	RMS	2.2 nm	60.4 nm

The mode indicator function, sum of squared Frequency Response Functions (FRF), indicates vibration modes between 24 and 40 Hz (Fig. 7). According to previous experience, these are likely to be related to rigid body rocking of the entire unit on the alignment feet and will be mitigated once the unit is grouted to the floor. Comparison with the integrated RMS function between detector and floor indicates significant contribution to the total RMS at 48.6 Hz originating from the floor that will prevail even after grouting. This can be accepted if the RMS displacements are below the specified limit as in this case.

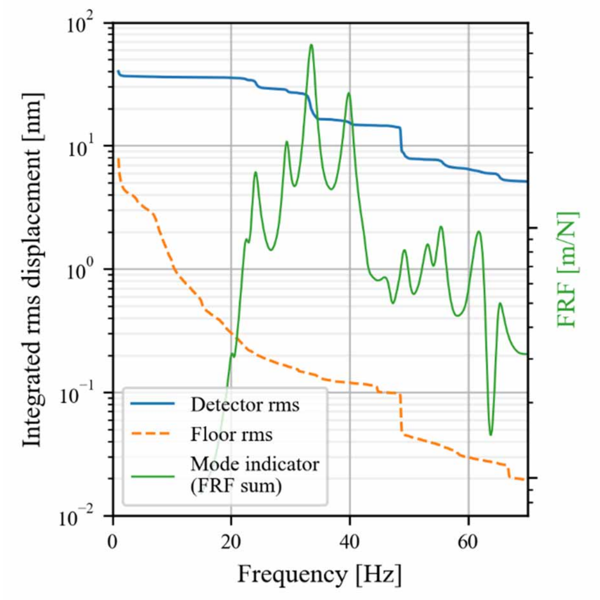

Figure 7: Integrated RMS of horizontal displacement (left y-axis) and mode indicator (right y-axis).

CONCLUSIONS

The Detector Stage has been designed, installed, and tested. Results have overall been satisfying and fulfil the specifications.

REFERENCES

[1] C. Colldelram, C. Rudget, and L. Nikitina, “ALBA XALOC beamline diffractometer table skin concept design”, *Diamond Light Source Proceedings 1(MEDSI-6)*, Oct. 2011. `doi:10.1017/S2044820110000754`