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ALL APPLICATIONS OF THE ALBA SKIN CONCEPT

Llibert Ribóa†, Nahikari Gonzalez[1], Joaquín González[2], Alejandro Crisol[1],
Antonio Carballedo[1], Luke Adamson[3], Elliot Reece Jane[4], Claude Ruget[1],
Judith Juanhuix[1], Josep Nicolas[1], Carles Colldelram[1],
[1]ALBA Synchrotron , Carrer de la Llum 2 26, 08290 Cerdanyola del Vallès, Spain
[2]MAX IV Laboratory, Lund University, Box 188, SE 221 00 Lund, Sweden
[3]Australian Synchrotron, 800 Blackburn Rd, Clayton VIC 3168, Melbourne, Australia
[4]FMB Oxford, Ltd. Units 1 4 Ferry Mills, Osney Mead, Oxford, OX2 0ES, United Kingdom

Abstract

During the ALBA design phase, the protein macromolecular protein crystallography beamline, XALOC, required several in-house developments. The major part of these designs was at the end station where the necessity of customization is always much higher. The most relevant of these instruments was the beam conditioning elements table [1]. This accurate stage, which supports the diffractometer as well, includes the four movements required to align the components to the nominal beam as well as position the diffractometer. This design compacts, especially the vertical and pitch movements, both in a single stage, with a couple of stages for all four excursions. The solution maximises the stiffness and preserves at the same time the resolution close to 0.1µm while being able to withstand a half tone of payload. Thanks this compactness and performances this design concept, the vertical and pitch combined stage, was not only applied at XALOC for its diffractometer and detector table, but it has been widely adapted at several ALBA beamlines: at NCD-SWEET [2] as a detector table, a beam conditioning elements table [3] and sample table, at MSPD beamline as the KB table, at NOTOS beamline as metrology table, and also at the new ESA MINERVA beamline [4] for their sample mirror modules positioning. Beamlines have not been the only beneficiaries of this design, also different kind of instrumentation like an hall probe measuring bench [5], and even a stitching platform for the ALBA optics laboratory [6]. Moreover, the concept has outreach ALBA and has been adopted also at other facilities worldwide, synchrotrons and also scientific instrumentation suppliers around Europe. This poster presents most of the applications of the skin concept and their variations and main measured performances.

INTRODUCTION

The original design of the ALBA Skin Concept Design [1] was the diffractometer and beam conditioning elements table for the protein macromolecular protein crystallography beamline, BL13 XALOC [7]. The beamline has a simple optical lay-out based in three main instruments a S111 channel-cut DCM monochromator and a Kirkpatrick-Baez (KB) mirrors pair. The different beamline configurations, vertically and horizontally mirrors focus or unfocused, divert the beam at sample position. The diffractometer, the sample, has to follow the beam excursions. Moreover, the previous beam conditioning elements have to be aligned jointly with the diffractometer, to the beam. All this system has to be positioned not only on position but also colinear with the beam path. These requires for this positioning system four axis (vertical, transversal, pitch and yaw), with resolutions well below 1 µm and 1 µrad for ranges up to 70 mm for the translations and 15 mrad for the rotations. In addition, these specifications have to be met still being able to withstand heavy load capacity, up to half a tone, and at the same time being accurate and stable.

† lribo@cells.es

ORIGINAL DESING

High payload, accuracy, resolution and stability are requirements that are very difficult the achieve all together. Moreover, the diffractometer and beam conditioning elements define an elongated shape. In order to achieve proper performance for all characteristics at the same time it was proposed the skin concept [1] where vertical translation and pitch where compact in a single stage as well as for the transversal and yaw movements.

While accuracy and resolution, but also the payload, are assured by means the quality of the mechanical elements the stability is achieved by several different strategies. The quality of the mechanical elements is guaranteed selecting the proper supplier's: high precision preloaded linear guides and oversized balls grind spindles for instance. In the other hand the stability approach is based on a design architecture intrinsically stable: using a big granite reference base, compacting movements by pairs: a translation and a rotation in a single stage, placing these stages surrounding the granite base (skin concept), with approach the loads are as close as possible to the granite minimizing the mass level arms, etc… With this configuration, especially for the combined vertical and pitch movements, the stage is placed like an inverted U shape along the granite with a vertical motion at each of the longitudinal extremes of the granite, light grey at Fig. 1a. A motor synchronized motion

(a) (b)

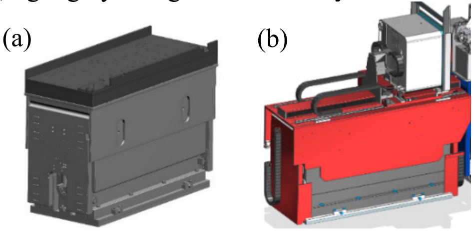

Figure 1: a) ALBA BL13 Diffractometer table. b) 3D model of the BL13 XALOC detector table.

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delivers the vertical translation while a differential motion the pitch. This layout takes advantage of the elongated shape to place the two motions as separate as possible, longitudinally, maximizing the counter-level arm supporting the mass and thus the maximizing stability but also contributing to a smoother angular resolution thanks again to the long level arm. The transversal movement and the yaw pair have a similar concept and they are described the original design paper [1].

APPLICATIONS

The solution has demonstrated a proper performance on resolution, accuracy and stability. For all these reasons this design has been adopted in many applications at ALBA. Some of these applications almost exactly copied the full concept and in others partially and/or with some adaptations. In specific applications the solution needs larger angular ranges, beyond the limits of a flexure option for the pitch. In other applications the pitch solution has been rotated to work as a Roll angle. Also, different flexure approaches have been developed improving further the range and stability. It has been adapted mainly for beamline End Station, but also for beam line optics, Insertion Devices hall probe measurement benches, optical set ups, at ALBA but also at other facilities like the Australian Synchrotron, MAXIV and also suppliers like FMB Oxford.

In the following list there is the known applications:

- The Diffractometer and beam conditioning elements table [1] at BL 13 XALOC beamline, ALBA.
- The Detector table at BL 13 XALOC beamline, ALBA.
- The KB and beam conditioning element table at BL04 MSPD beamline, ALBA.
- The detector table at NCD-SWEET Beamline, ALBA.
- The sample table [2] at NCD-SWEET Beamline, ALBA.
- The beam conditioning element table [3] at NCD-SWEET Beamline, ALBA.
- The KB Table at XFM [8] beamline at the Australian Synchrotron.
- The Closed Gap Hall Probe Bench [5] for the Insertion Device laboratory at ALBA.
- The Lorea M3 & M1 mirror mechanics at ALBA by FMB Oxford.
- The Fizeau System Instrument [6] at ALBA optics laboratory.
- The Sample Table at ForMAX beamline at MAXIV.
- The Sample Chamber at the BL25 MINERVA beamline for ESA at ALBA
- The Metrology Table at BL16 NOTOS beamline, ALBA.

Different Adaptations

Following are described the most relevant variants of the skin concept. The NCD Sample Table, Fig. 2a, requires an extended Pitch angular range up to ±10º. The design has been modified including a roller, bearing, articulation to allow this range instead of a flexure. As the angular range is large it is needed a distance relieve guide, passive, to compensate the length variation. The bearing articulation allows large angular movements thus this now is not the limitation for the angular range it become limited only by the vertical stages ranges. The articulated solution introduces much less stresses to the parts and loads to the motion, but it becomes a much noisy movement as it can be seen in the following chapter of comparison results, Fig. 5.

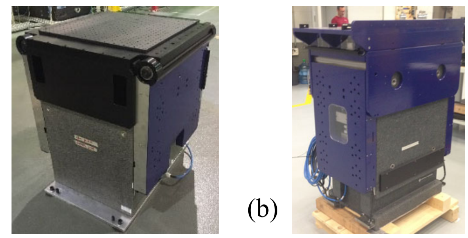
(a)

(b)

Figure 2: a) Sample Table for BL11 NCD-SWEET beamline with bearing articulated pitch. b) Beam conditioning elements table for BL11 NCD-SWEET beamline.

Another evolution of the table it is an optimization of the pitch flexure made at Australian Synchrotron [8]. Four possible improved flexures, Figs. 3a and 3b, were analysed and the better results were for 90º Cross Hinge.

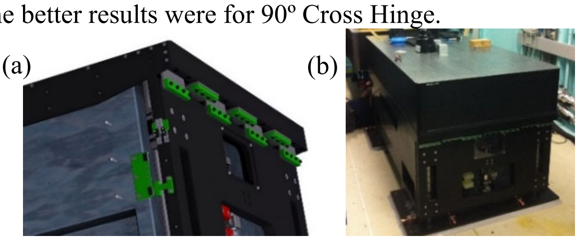
(a)

(b)

Figure 3: The KB Table at XFM beamline, Australian Synchrotron. a) Detailed view of the 90º Cross flexure hinge. b) picture of the KB table.

The conventional flexures are designed with high elastic limit steels, for the first design 1.2738 with an elastic limit about 780 MPa. This material is treated, hardened, material that does not need further process to reach its final characteristics and the treatment reaches the full bulk of the material, thus keeping these properties for the flexure slots. Despite these properties it still maintains a friendly machineability. The final calculated stress on the flexure was about 270 MPa which is about 35% of the yield stress, thus well below the 40% taken as a reference for generic fatigue limit. Moreover, from the material supplier the raw material has to be cut with steel fibber placed properly oriented vertically to ensure the material works properly. In addition, for each project a material test probe is done to verify the offered yield stress. The 90º cross flexure hinges solution simplifies the design and production and give an improved stability up to 85 Hz for the first resonance mode.

RESULTS

Most of the projects have been measured by means optical metrology. The original paper [1] shows the results for the first table. The several applications of this concept allow for very reliable comparison of different mechanical solutions as all them are very similar. One important point to evaluate is the effect of the table length on the Pitch, not

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only level arm resolution conversion but mainly on the quality of this parameter. One of the longest applications is the BL13 XALOC detector table, Fig. 1b, with a granite length about 1,5 m and one of the shortest that can be compared is the beam conditioning elements table for BL11 NCD-SWEET beamline with a 650 mm granite length, Fig 2b.

Figure 4 shows the resolution graphs for both applications, both for 1 full step. Taken in account the reduction ratio, the length of the granite, the resolution of the beam conditioning table has to be twice(half) of the detector table and considering this, the major difference is the level arm. Both graphs show a clean resolution and show clearly one is twice the other for a full step motion, but it is possible to see a cleanest resolution for the longer table solution. Thus the level arm contributes to refine the resolution better than use mechanical elements like the reducer. Another relevant comparison is the flexure vs bearing articulation solution. Other comparable projects which there are metrology measurements are the Sample Table, Fig. 2a, and beam conditioning element table, Fig 2b, both at BL11 NCD-SWEET beamline. Motors and spindles are equivalent. The motor reduction ratio is 64 and 100 respectively. And the granite length is rather similar 605 and 648 mm.

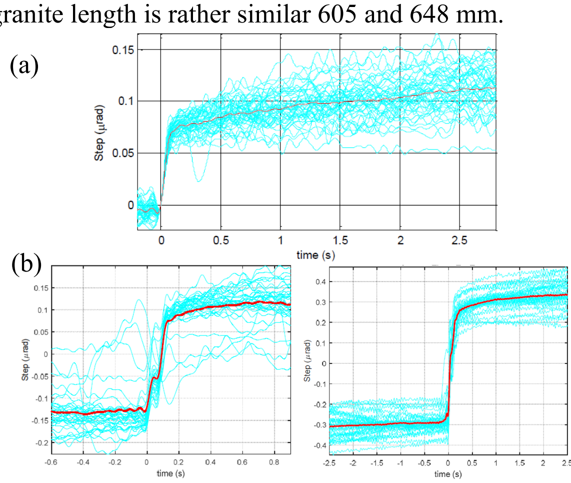

Figure 4: a) Resolution at 1 full step of the BL13 XALOC detector table. b) Resolution at 1 & 2 full steps (Figure b1 & b2) of the beam conditioning elements table for BL11 NCD-SWEET beamline.

As the reduction ratio is close to be one the double of the other it can be compared by 1 full motor step graphs Fig. 4b1 vs Fig. 5b, or by equivalent resolution steps Fig. 4b2 vs Fig. 5b and Fig. 4b1 vs Fig. 5a. It is clearly visible that the resolution of the bearing articulation is much more noisy, non-uniform, than the flexure. In addition, the repeatability is much better for the flexure solution 0,7 µrad vs 2 µrad of the bearing articulated table.

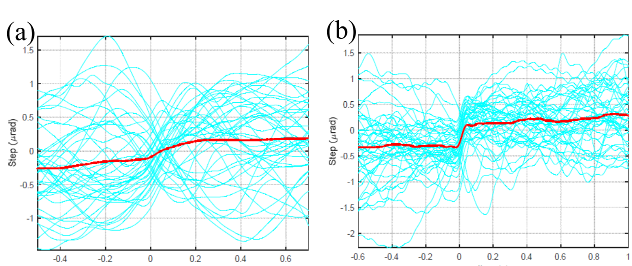

Figure 5: Resolution at 1 and 2 half steps (5a & 5b) of the sample table for BL11 NCD-SWEET beamline.

CONCLUSION

The skin concept table is a very good solution reaching at the same time performances that are very difficult to meet with the same mechanics: high payload, accuracy and resolution, and stability. The solution has successfully been adopted for many other applications successfully: for other similar end station applications, for optics mechanics, for measurement benches at ALBA and other synchrotrons and even their suppliers. New solution haves further improve the stability and in other cases increase the functional range but relaxing the motion performances. It gives the opportunity to test the same conceptual solution in different adaptations but allowing a very reliable comparison between different mechanical approaches. The skin concept design strategies are: chose a stable reference (a granite for instance), place the masses close to this reference, reducing payload and mass level arms, compacting: two movement in a single stage, but increase the motion level arm for angular movement like the pitch solution. The results could give some design principles guides for better motion and stability performances. These performances can be easier achieved by the mechanical architecture design, mechanical configuration and shape, rather than charge on the components (linear guides, spindles). This means: placing the supporting components, the spindles for this case, as separated as possible, maximizing the counter-level arm to support the weights (the masses) rather than increase this spindle size; this geometry also maximize the pitch resolution by, in this case, maximizing the length, but in general maximize the angular motions level arms than rely on increasing the motor reducers ratio. And finally, when possible, include flexure hinges, when the range allow for it, instead of placing ball bearings articulations in general than roller components for articulations despite its fine movement.

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REFERENCES

[1] C. Colldelram and Claude Ruget, "ALBA XALOC Beamline diffractometer table skin concept", in *Proc. MEDSI'10*, Oxford, UK, Oct. 2011, Diamond Light Source Proceedings, vol. 1, e44. doi:10.1017/S2044820110000754

[2] J. B. González *et al.*, "NCD-SWEET Beamline Upgrade", in *Proc. MEDSI'18*, Paris, France, Jun. 2018, pp. 314-376. doi:10.18429/JACoW-MEDSI2018-THPH17

[3] N. González *et al.*, "Beam Conditioning Optics at the ALBA NCD-SWEET Beamline", in *Proc. MEDSI'18*, Paris, France, Jun. 2018, pp. 365-367. doi:10.18429/JACoW-MEDSI2018-THPH14

[4] A. Carballedo *et al.*, "X-Ray Facility for the Characterization of the ATHENA Mirror Modules at the ALBA Synchrotron", presented *at* MEDSI'20*,* Chicago, USA, Jul. 2021, paper WEPA12, this conference.

[5] L. Ribó and C. Colldelram., "Hall probe bench prototype for closed magnetic structures", in *Proc. MEDSI'14*, Melbourne, Australia, Oct. 2014.

[6] L. Ribó and C. Colldelram., "The Fizeau System Instrument at ALBA Optics Laboratory", presented at *MEDSI'20*, Chicago, USA, Jul. 2021, paper WEPA07, this conference.

[7] J. Juanhuix *et al.*, "Developments in optics and performance at BL13-XALOC, the macromolecular crystallography beamline at the Alba Synchrotron", *J. Synchrotron Radiat.*, vol. 21, p. 4, Jul. 2014, pp. 679-689. https://doi.org/10.1107/S160057751400825X.

[8] L. Adamson and Adam Walsh, "X-ray Fluorescence Microscopy End Station Upgrade", presented at MEDSI'14, Melbourne, Australia, Oct. 2014, unpublished.