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BEAM CONDITIONING OPTICS AT THE ALBA NCD-SWEET BEAMLINE

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Abstract

The SAXS/WAXS Experimental End Station beamline (NCD-SWEET) at ALBA Synchrotron has undergone a major upgrade in the optics and the end station to perform state-of-the-art SAXS/WAXS experiments.

In order to reduce X-ray parasitic scattering with air and maximize the photon flux at the sample, an optimized beam conditioning optics has been designed and built in the end station, integrating previously used and new components in vacuum.

The beam conditioning optics includes a fast shutter, a set of commercial guard slits and a diagnostic unit comprising three filters and a four-quadrant transmissive photodiode. In addition, a set of refractive beryllium lenses allows micro focusing of the beam. The lens system can be removed from the beam path remotely. Finally, an on axis sample viewing system, with a novel design based on an in-vacuum camera mirror and a mica window minimizes the beam path in air up to the sample.

To facilitate the alignment of the elements with respect to the beam, all the subsystems are supported by a high-stability granite table with 4 degrees of freedom and submicron resolution.

INTRODUCTION

As part of the upgrade project of the the Non-Crystalline Diffraction beamline (NCD-SWEET) at ALBA, the end station has undergone a full re-design of the mechanical elements in addition to the installation of new equipment with the result of a new beamline configuration [1].

In order to improve the service to users and provide an improved basic configuration to perform transmission experiments, an enhanced beam conditioning optics system comprising new elements such as, a diagnostic unit and a set of micro focusing lenses, has been designed and built (Figure 1). Additionally, the vacuum section has been extended up to the sample and all the components have been located over an in-house developed 4-DOF granite table.

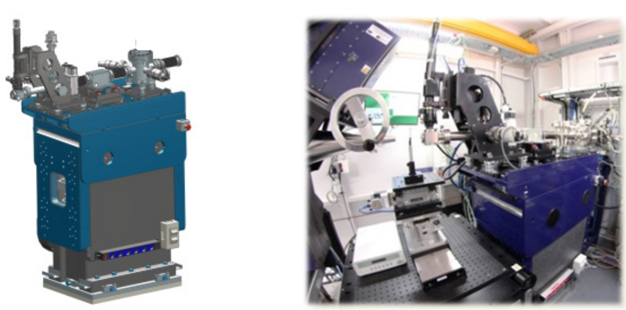

Figure 1: General overview of the Beam Conditioning Optics.

SYSTEM REQUIREMENTS

The main objective of the beam conditioning optics (BCO) upgrade was to maximize the beam transmissivity up to the sample, thus, all the elements, including the fast shutter and the on-axis sample viewing system (in air in the previous setup), were placed in vacuum. Besides, in order to have a diagnostic of the beam intensity just before the sample a new diagnostic unit compounded of a transmissive photodiode and 3 filters had to be installed. Additionally, a set of compound lenses were integrated. These lenses can be remotely inserted into the beam path in order to micro focus the beam.

So as to ease the alignment of the beam conditioning elements with respect to the beam for different optical configurations and energy ranges while ensuring the system stability, all the components had to be located over a high stability 4-DOF table.

The movement requirements of the support table are listed in Table 1.

Table 1: Motion Requirements of the BCO Support Table

	Range	Resolution
Vertical	15mm	2 µm
Transversal	± 5 mm	2 µm
Pitch	±0.5˚ (± 8.5 mrad)	±0.001˚ (17. 4 µrad)
Yaw	±0.5˚ (± 8.5 mrad)	±0.001˚ (17.4 µrad)

DESIGN DESCRIPTION

The beam conditioning optics system consists of a granite based table with 4 motorized degrees of freedom that allows the alignment of the elements with respect to the beam while ensuring the stability of the components. All the beam conditioning elements, namely, the fast shutter, the compound refractive lenses, the slits, the diagnostic unit and the sample viewing camera mirror are placed inside UHV vessels located over the table. The elements have external fiducial interfaces and individual alignment stages, with edge welded bellows in between, so that all the apertures could be pre aligned during the installation. Besides, the beryllium lenses system is located over two motorized stages that permit the in-out motion and the longitudinal positioning along the beam path for the focal position adjustment. This motion, together with the vertical movement of the on axis camera that permits the focusing adjustment, gives high versatility for using sample holders of distinct sizes.

Microfocusing Lenses

A set of 35 beryllium compound refractive lenses permit micro focusing the beam at 664mm from their centre. The lenses are positioned within a vacuum chamber lo-

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cated over an in-house designed two linear motions motorized stage of sub-micron resolution (Figure2). The transversal motion allows the positioning or removal of the lenses in the beam path and the longitudinal motion permits to adjust the focal point for diverse sample environments. Going from standard configuration to micro-focused beam (or the other way around) is fast and only takes 10s.

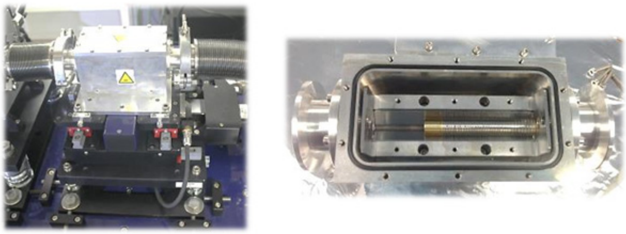

Figure 2: Images of the micro focusing lenses unit.

Diagnostic Unit

The system consists of a motorized horizontal linear motion with 4 discreet positions for different filters: none, Cobalt, Copper and Zink, and an independent vertical linear motion for a photodiode, located just upstream the filters (Figure 3). The transmissive photodiode is a 5x5mm^2 area and 10µm thickness Si diode, developed in collaboration between ALBA, ESRF and IMB-CNM-CSIC [2]. It enables having a diagnostic of the beam intensity and vertical position just before the sample. The diode has been calibrated and provides absolute flux. The three filters are used together with the data collected at the diode for energy calibration.

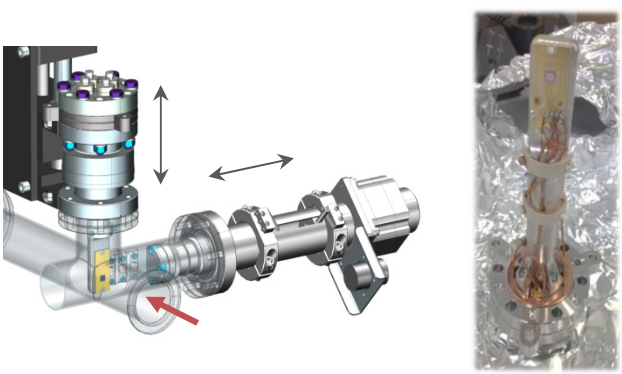

Figure 3: Pictures of the diagnostic unit.

On Axis Sample Viewing System

The on-axis viewing system is based on a novel design consisting of an in-vacuum mirror and an imaging system (commercial Navitar lens with a CCD camera) located in air. The mirror, located at 45˚, is made in-house from a hard disc platter with an Ø1mm central hole for the beam. It is separated from air by a 50µm mica window at the sample side and by a fused silica viewport and an in-house developed and patented double O-ring sealing [3] on the side of the camera lenses (Figure 4).

Besides, the camera is equipped with a vertical motion system to adjust the focal plane at sample position. The lens can be easily re-configured in order to focus at larger distances, although at the expense of magnification, thus providing an enhanced versatility in regard to the different sample holder sizes/types.

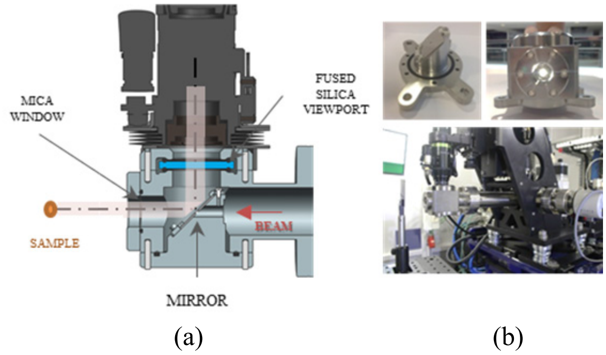

Figure 4: Sample viewing system scheme (a) and mirror, mirror support and mirror chamber (b).

Support Table

The support table is based on the in-house developed “skin concept” design which provides high stability and excellent resolution performances [4]. The motion stages are mounted as close as possible to the fixed block of natural granite, minimizing the mass lever arms and thus optimizing the stability.

Vertical movement is performed by a simultaneous displacement of the front and back rigid plates, which are connected on the top by a horizontal plate. The pitch motion is achieved by a differential movement of these two plates, which are flexure grooved (Figure 5).

Transversal movement is carried out by a linear guided stage, actuated by motors and precision ball screws on both sides. The yaw, guided by circular guides, is performed when actuating the upstream motor alone. The rotational movement on the motion system of the yaw is relieved by a flexure link.

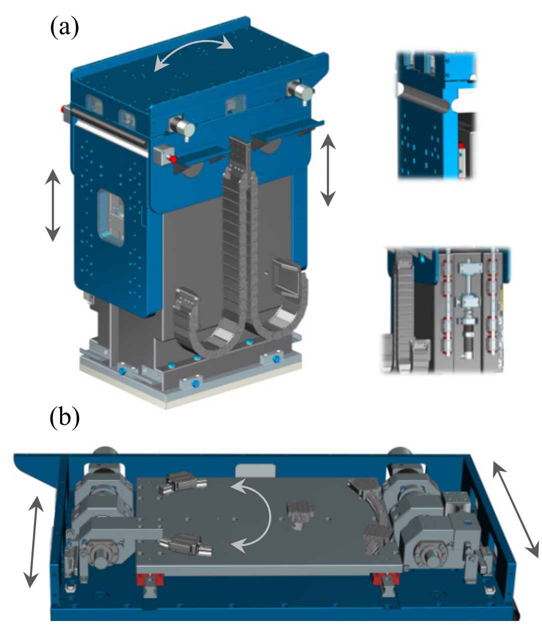

Figure 5: Vertical and pitch motions (a) and transversal and yaw motions (b).

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FINITE ELEMENTS ANALYSIS

In order to study the behaviour of the whole system, both structural and modal finite elements analyses were performed in Ansys.

Structural Analysis

The maximum deformation and stresses of the BCO were 94µm and 20MPa respectively, well beyond the maximum admissible values in order to assure the correct performance of the system. Besides, the maximum stresses on the flexures for the pitch and yaw rotations were calculated, obtaining a maximum stress value of 340MPa, which is 1/3 below the yield stress of the high elastic limit steel used.

Modal Behaviour

A frequency analysis was also performed in Ansys to evaluate the stability of the overall system. The first 4 modes of vibration are shown in Figure 6.

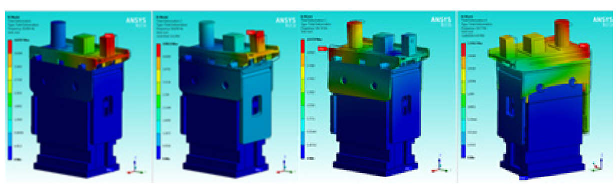

Figure 6: First four eigenmodes of the BCO; 58Hz, 84Hz, 100Hz and 103Hz respectively.

PERFORMANCE & RESULTS

Metrology Results

Metrology tests were performed using a Renishaw ML10 Interferometer in order to evaluate the performance of the different motions of the BCO support table. The results of resolution and repeatability measurements are shown at Table 2.

Table 2: BCO Support Table Metrology Results

	Stroke	Resolution	Repeatability
Vertical	90 mm	0,125µm	2,016 µm
Transverse	± 20 mm	0,313µm	0,598 µm
Pitch	± 9,2 mrad	0,125µrad	0,702 µrad
Yaw	± 14,6 mrad	0,313 µrad	1,259 µrad

In addition, vibration tests were executed measuring the amplitudes when exciting the system with a hammer at different locations. The results quite well match with the FEA simulation results.

Table 3: Vibration Tests Results

Location	Frequencies (Hz)
Upstream	84, 92
Downstream	84, 92
Inboard	54, 65, 84, 92, 113
Outboard	56, 84
Top	53, 65, 84, 92

On Axis Viewing System

An extensive commissioning on the on axis viewing system was performed in order to evaluate the image quality provided by the in vacuum camera mirror with the mica window sealing. Several pictures of distinct zooms are shown in the Figure 7. The field of view (FOV) at maximum zoom (Magnification) of M=5.66X is 0.85x0.64mm (H x V).

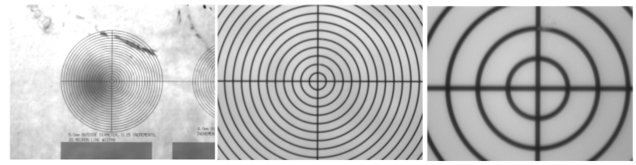

Figure 7: Test images for a 5mm diameter reticule with 0.25mm diameter increments and 0.02mm line width.

CONCLUSIONS

In summary, the overall design of the beam conditioning elements at the recently upgraded NCD-SWEET beamline has been presented, including the detailed description and results of the support table that validate the enhanced performance and stability of the system.

The beam conditioning optics assembly was installed during the summer shutdown of 2017 and it is currently used by the users. Further commissioning for optimization will be performed during this year.

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