ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-THPH15

A NEW HIGH PRECISION, FULLY MOTORIZED 6-DoF SAMPLE STAGE FOR THE ALBA PEEM ENDSTATION

N. González†, L. Aballe, A. Carballedo, C. Colldelram and M. Foerster
ALBA Synchrotron Light Source, Cerdanyola del Vallès, Spain

Abstract

A new 6-DoF sample manipulator has been designed for the ALBA Synchrotron PhotoEmission Electron Microscopy (PEEM) experimental station, based on a commercial Elmitec LEEM 3.

The new design includes full motorization of all 6 axes with position feedback, no backlash, and maximized stability, crucial to achieve the best spatial resolution of down to 8 nm (in so-called LEEM mode).

The in-plane longitudinal and transversal motions with sub-micron resolution are based on high precision linear guides, while the pitch and roll stages (sample tilt), guided by angular guides, are actuated by a double-flexure system, which enhances the overall rigidity of the system. The vertical stage is composed by a high rigidity recirculating roller screw and cross roller guides. Finally, 360˚ yaw rotation is supplied by a differentially pumped commercial rotary stage. On top of the stage, the sample support is mounted on a customized DN63CF flange.

This support keeps the original functionalities of the sample manipulator and holders, with 6 independent electrical contacts, and the possibility to heat the sample up to 2000 K and cool it to 100 K with an improved liquid nitrogen cooling system.

INTRODUCTION

The purpose of the project is to upgrade the PEEM endstation functionality by offering full automatization of the sample motions. In the present form, the vertical motion and the crucial sample tilt (which through non-geometrical effects is coupled with the measurement position (horizontal stage)) are still operated manually, preventing full remote control and programming of sequences.

Additionally the new design offers opportunities to improve repeatability of those motions already motorized, the easy integration into the control system through ICEpap motor controls and the improvement of the cooling stage efficiency which has deteriorated in the original design. Improvement of the sample stability, which is straight related with the microscope resolution, is also sought.

TECHNICAL SPECIFICATIONS

The main objective of the new design of the sample manipulator is to motorize the 6 degrees of freedom that allow the alignment of the sample with respect to the microscope (main) objective lens (field of view). The motions must guarantee the correct positioning of the sample and repeatability while most of all ensuring stability, which directly influences the microscope resolution. Besides, a longer vertical movement is required in order to move the sample holder to the transfer position.

In addition, the existing liquid nitrogen cooling system has to be improved in order to obtain 100K at the sample.

The stage must be placed over the analyser chamber at the PEEM experimental station (Figure 1) so the overall system must be as compact as possible to reduce the mass over the chamber, maximize stability and leave free space for the surrounding instrumentation.

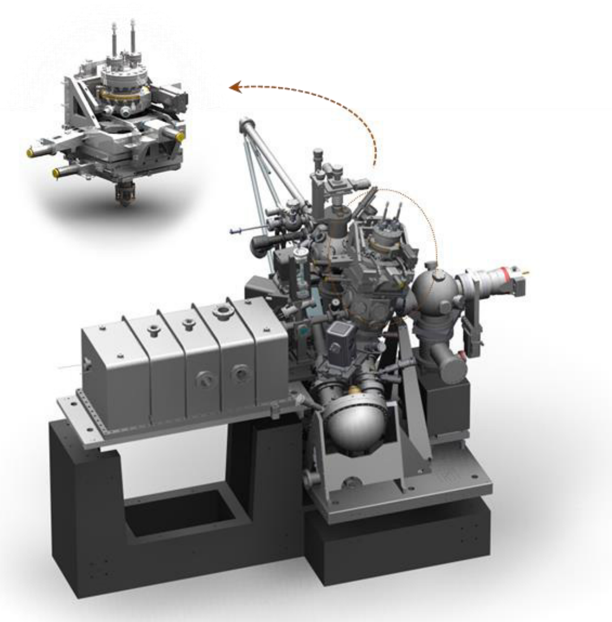

Figure 1: General view of the sample stage location at the PEEM End Station.

Moreover, the new sample stage must comply with the following specifications:

- To be UHV compatible and bakeable.
- To be compatible with the standard Elmitec sample holders.
- To keep 6 independent electrical contacts at High Voltage (20kV)
- Possibility to heat the sample up to 2000K.
- Possibility to cool the sample down to 100K.

† ngonzalez@cells.es

Mechanical Eng. Design of Synchrotron Radiation Equipment and Instrumentation MEDSI2018, Paris, France JACoW Publishing
ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-THPH15

SYSTEM DESCRIPTION

Motion Stages

The presented solution consists of a horizontal stage in which the longitudinal and transversal linear movements are performed by high precision ball screws and cross roller linear guides.

Relative to the latter, a double angle goniometer mechanism enables the pitch and roll rotations. The linear motion on the ball screws is transmitted to the square frames guided by angular guides, which have the center of rotation at the intersection between the theoretical X ray beam and the objective axis. The small rotation between the ball screw nut and the angular motion is relieved by a double-flexure that enhances the stability of the system.

On top of the goniometer, the vertical stage is compounded by a high rigidity recirculating roller screw and cross roller guides. Finally, yaw rotation is provided by a commercial differentially pumped rotary stage.

All the movements (Figure 2) are actuated by low-backlash stepper motors and include encoder feedback. An edge welded bellow mounted on the manipulator base allows transmitting the movements in air to the sample support in UHV.

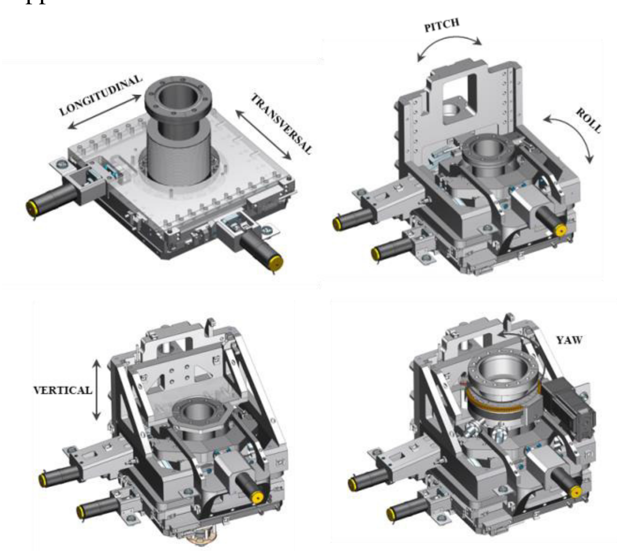

Figure 2: Pictures of the different stages that provide six degrees of freedom.

Sample Environment

The sample support (Figure 3) consists of a customized CF63 flange mounted on top of the rotary stage with a support tube in UHV that carries the sample holder interfaces at the tip in. The flange includes two CF25 flanges for the liquid nitrogen supply connections and the electrical connections at the tube end.

The sample tip, which has not been modified with respect to the existing design from Elmitec, includes 6 electrical contacts and it is connected to the support tube by means of a ceramic brazing that acts as electrical insulator. Besides, the sample holder interface is supported by 6 sapphire rods that also act as electrically insulating thermal conductors in order to cool the sample holder support from the liquid nitrogen circuit.

The manipulator tip can be easily extracted for maintenance purposes without disassembling the manipulator mechanics.

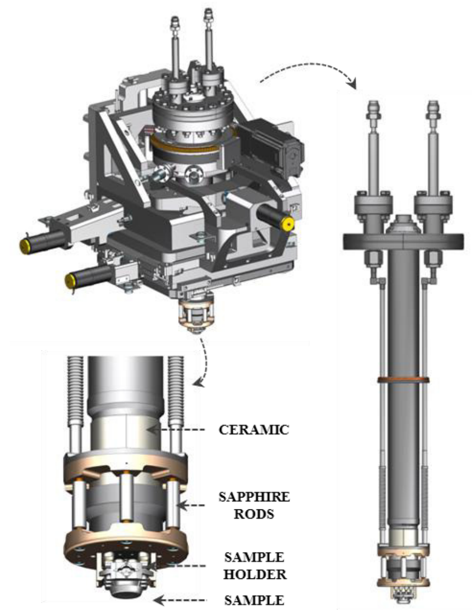

Figure 3: Pictures of the sample support.

Cooling Circuit

The cooling circuit has been upgraded so that the cooling pipes do not have any relative movements that could deteriorate the thermal conductivity up to the sample support. The tubes are connected to vacuum insulated VCR connections and they are linked to a liquid nitrogen reservoir that cools down the sample support by means of turbulence suppressive low-vibration hoses that absorb the thermal deformations of the tubes and reduce the vibrations caused by the liquid flow (Figure 4).

The use of feedthroughs designated for cryogenics should improve the long term reliability of this UHV seal, which has the risk of becoming leaky with time in the original design.

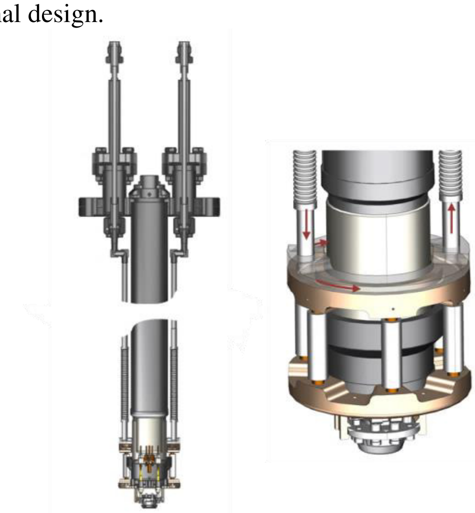

Figure 4: Liquid nitrogen cooling circuit.

ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-THPH15

SIMULATIONS

Static Behaviour

Different calculations by means of FEA have been done in order to achieve the standards of safety and technical specifications. Boundary conditions of gravity and vacuum forces were considered. The resulting displacement on the sample position (Figure 5) and maximum stress under static behaviour were 0.14 mm and 35 MPa respectively.

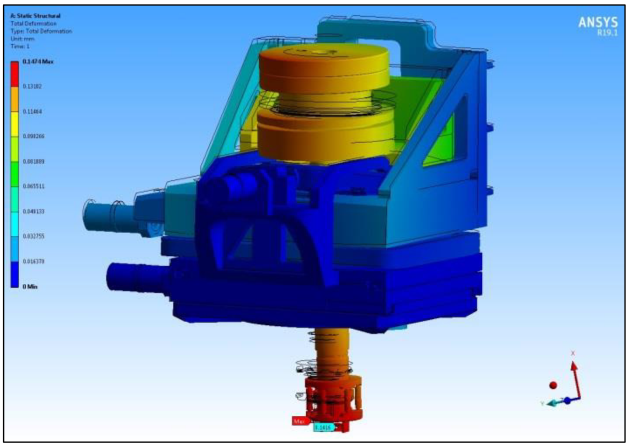

Figure 5: Displacement under static behaviour.

Regarding the stress on the flexures when pitch and roll are actuated, the resulting values were 830 MPa and 826 MPa respectively (Figure 6). Due to the critical stress that appeared on the flexure line, a high performance Cr-Mo-V steel alloy has been selected, which provides a yield strength of 1800 MPa.

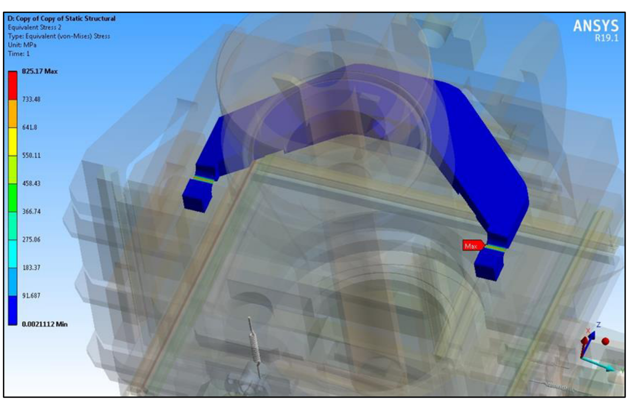

Figure 6: Stress on Roll Flexure.

Modal Analysis

Several FEA calculations studying the free vibration behaviour were done. Figure 7 shows the sample manipulator first and second resonance mode (RM). The resulting values were for 1st RM of 64.8 Hz and 2nd RM of 67.4 Hz. All values are shown in Table 1, corresponding to pitch and roll rotations on the sample respectively.

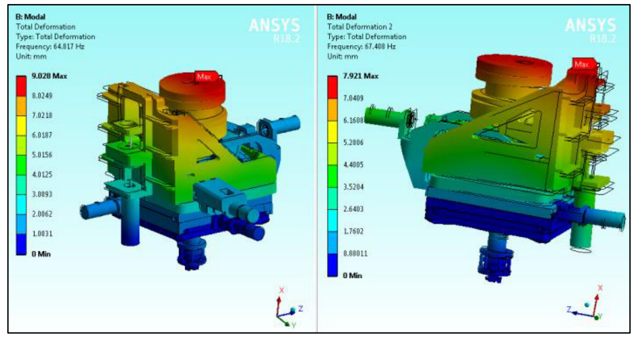

Figure 7: 1st and 2nd RM results.

Table 1: Sample Manipulator Resonance Modes

Mode	Frequency [Hz]
1	64.8
2	67.4
3	108.3
4	111.0
5	127.0
6	129.9

CONCLUSIONS

In conclusion, the development of this project has result in a compact and fully motorized 6-DoF sample manipulator. Keeping the UHV compatibility on the sample environment, enhanced functions have been integrated like the new cooling system and high precision and repeatable movements.

Even though the sample manipulator performance has been not tested yet, it is expected to obtain a maximized stability on the system, crucial to achieve the best spatial resolution on the PEEM station.

The accomplished requirements are shown at Table 2.

Table 2: Manipulator Motions Compliance Table

		Required	Accomplished
X and Y	Range	± 5 mm	± 5 mm
	Resolution	0.5 μm	0.2 μm
Vertical	Range	43.75 mm	57 mm
	Resolution	0.1 μm	0.035 μm
Roll and Pitch	Range	±2˚	±2˚
	Resolution	0.35 mrad	0,001 mrad
Yaw	Range	360˚	360˚
	Resolution	0.02˚	<0.01˚

The design, which is currently under production, will be tested and installed during the end of year 2018.

ACKNOWLEDGEMENTS

The authors wish to acknowledge all the ALBA staff involved in the design of the high precision sample stage, in particular, Marta Llonch, Jon Ladrera, Liudmila Nikitina, Gabriel Peña, Abel Fontseré, Fulvio Becheri, Josep Nicolás and Jordi Prat.