9th Edit. of the Mech. Eng. Des. of Synchrotron Radiat. Equip. and Instrum. Conf. MEDSI2016, Barcelona, Spain JACoW Publishing
ISBN: 978-3-95450-188-5 doi:10.18429/JACoW-MEDSI2016-WEPE37

UPGRADE OF THE SUPER ADVANCED X-RAY SPECTROMETER (SAXES) OF THE RIXS ENDSTATION FOR BETTER RESOLUTION AND LARGER DETECTOR SIZE

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Abstract

The RIXS endstation of ADRESS beamline at Swiss Light Source (SLS) is equipped with an ultrahigh resolution X-ray spectrometer as described in [1]. In the scope of a CCD camera upgrade, the modification of the vertical alignment of the guiding structure and ultra-high vacuum tanks became necessary. The new camera with a higher resolution and larger detector size weights around 25 kg. It is required to have a vibration-amplitude well below 2 microns. We will present the critical design parameters of the upgrade, and the effort to increase bending stiffness of vacuum guide structure while keeping major geometry parameters. In addition, kinematic over determinacy was removed. After the upgrade we performed vibration measurements verifying that the dynamic stability of the camera is improved, and the design goal is reached. The site acceptance test confirmed the proper operation of the new mechanism. The redesigned spectrometer is shown in Fig. 1 with the welded bellows only connected on one side.

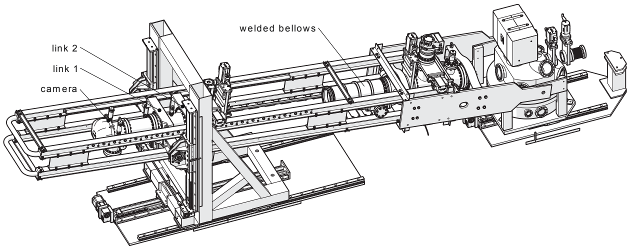

Figure 1: The redesigned spectrometer.

INTRODUCTION

The spectrometer with a length of 5 m is installed on a rotating girder platform and allows varying scattering angles from 30° to 130°. The position of the CCD detector is longitudinally adjustable on the girder and vertically adjustable on a moving frame to allow an angle between 2° to 15° in the vertical plane. For the new and much bigger detector system with 3 inches in width, the whole vacuum section and beam guiding chambers had to be enlarged to get use of a wider beam. The bigger ultra-high vacuum chambers and the new welded bellows were made of stainless steel 316LN.

The retrofit also included a new and larger turbo and ion getter pump as well as an automated vacuum valve on both ends of the bellow. The three separate vacuum compartments allow individual ventilation without ventilating the bellows. The retrofit was performed while aiming at the minimum number of changed parts.

The enlargement together with the new vacuum pumps would cause a substantial increase in weight. This could decrease stability of the instrument and it could require changes in the air movers or the girder. To increase the stability and to make sure the instruments weight and centre of gravity could be maintained, the whole supporting structure was built in aluminium with more efficient beam cross-sections. Therefore, the carrier structure is now built with 4 aluminium I-shaped beams with a higher stiffness than the old steel L-shaped beams but with lower weight. The same concept was adapted to the new camera support, which is now made of two big aluminium cross links about 50% lighter than the old design but much stiffer. The revolute joint of the camera support consists of much bigger self-aligning ball bearings, which allows compensation of inaccuracy in all required directions. Thus, the two linear drives at the mainframe are no longer fixed together by an overdetermined structure, they move simultaneous driven by the same motor. The linear bearing, which supports the connection of the carrier structure, also allows this compensation by using cam followers at the floating bearing side. The cam follower is a compact bearing with a high-rigidity shaft and a built-in needle bearing. Contrary to the normal installation case these rollers run on a hardened shaft guideway.

Figure 2: The spectrometer after the upgrade.

For the fixed bearing side normal linear ball bearings were used, running on the same type of shaft guideways. To support the new and bigger vacuum chambers, the carrier structure had to be redesigned and a new bellow guiding system was required. The vacuum chambers are carried by two big aluminium cross links, which allows linear displacement compensation in case of higher temperatures, such as a high bake out temperature of min.

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ISBN: 978-3-95450-188-5 doi:10.18429/JACoW-MEDSI2016-WEPE37

150 °C. Therefore another fixed and floating bearing concept was applied to cope with thermal elongation during bake out.

The new bellow has a diameter of 150 mm (DN150) and enables an elongation of 1700 mm. Therefore a new guiding system was designed, made of two linear ball bearing tracks fixed at the carrier structure. For the coupling between the bellow and the tracks there are special between rings welded directly in the bellow. This new system allows a save and smooth operation of the bellow within its whole elongation. The final spectrometer after the upgrade can be seen in Fig. 2.

KINEMATICS

According to the requirements, the Instrument parameters, the range and the drive elements shouldn't change. Only the rotation axis of the camera support had to be moved closer to the vertical guiding structure, to improve stability and the natural frequency of the supporting structure. The given kinematics was highly over determined, which lead to a poor regularity in operation. A new bearing concept was indispensable.

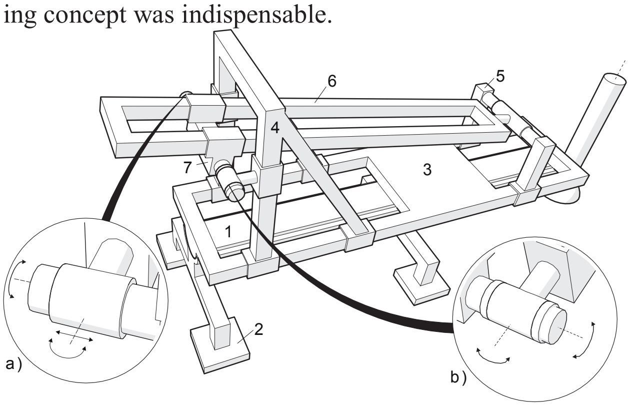

Figure 3: Kinematics of the spectrometer.

The kinematics of the spectrometer are shown in Fig. 3. The main platform (1) is carried by multiple air movers (2) to adjust the horizontal scattering angle from 30° up to 130°. On this platform there is an adjustable girder (3) to make sure that the instrument is aligned horizontally and independent form the inaccuracy of the air movers. On top of the girder the instrument is separated in two individual moveable parts. One is the mainframe support (4) and the other is the scattering grid chamber (5). Both of them are moveable along the longitudinal axis of the instrument to adjust the distance from the grating to the detector. These two parts are connected by a carrier structure (6) which carries the vacuum sections and guides the beam in an UHV environment of 10^{-9} mbar to the camera. To adjust the vertical angle of the carrier there is a joint at the scattering grid chamber and the carrier is moveable up and down along the mainframe support. The camera is mounted at the detector support (7) which connects the mainframe with the carrier structure. Thus, the detector support is movable in height and distance and is automatically aligned with the vertical angle of the carrier structure.

The new bearing concept enables the kinematics as described above, without being overdetermined but is on the other hand very stiff and stable. The bearings of the camera support were replaced with self-aligning ball bearings and linear ball bearings. Furthermore, one side has been designed as a floating bearing (a) and the other as a fixed bearing (b).

STABILITY AND PERFORMANCE

The design of spectrometer guide structures, and also the vertical alignment, has been modified as described above. The girder itself and the movers as well as the longitudinal positioning remain unchanged. Vibration measurements were performed before the upgrade on the original spectrometer in January 2015 and after the upgrade in June 2016 to verify the success of the project.

Initial Measurements

During the measurement period, ground vibration is instable and the calculated PSD displacements are all chosen to be in the quiet periods and are therefore not completely representative for the user operation. The girder itself shows low frequencies and a relatively high amplification ratio. Since the girder was beyond the scope of this project, its vibration remains determinative for the overall stability behaviour of the system.

Table 1: Displacement Amplification Ratio from Girder to Camera

Direction	Before Upgrade	After Upgrade
Vertical	4	3.2
Horizontal	4	2.5

Final Measurement

For the final measurement after the upgrade, the detector was driven to the upmost longitudinal position. Also the camera position is slightly higher than in the first measurement, to make sure that the new measurement is conservative. For the comparison of the two situations, the amplification ratio between the camera and the girder has been evaluated as shown in Table 1. The amplification ratio from the camera to the girder, especially in transversal direction, is much lower after the upgrade, manifesting the stiff structure and improved stability of the new camera support.

Ground vibration spectrum is not fully comparable with the measurements before the upgrade, with a higher vibration around 48 Hz in the second measurement. The displacement behaviour on the camera and articulation can be seen in Fig. 4. The measuring positions are indicated in Fig. 1. The eigenmodes of the structure are barely visible due to the low amplification.

The RMS displacement vertical to the beam from 5 to 200 Hz is below 100 nm and around 100 nm in horizontal direction. The specified camera movement of 2 microns is therefore fulfilled.

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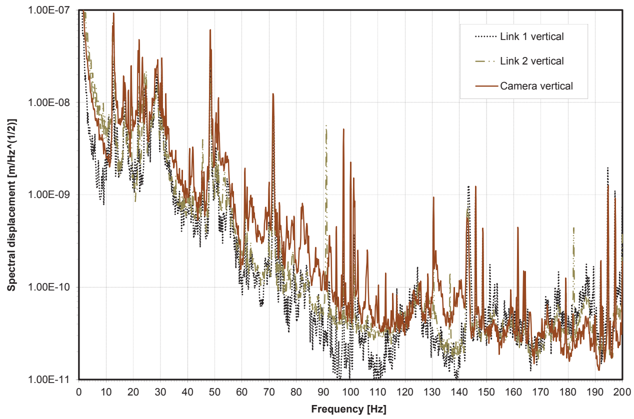

Figure 4: Displacement behaviour on the articulation.

CONCLUSION

The spectrometer features a new and stiffer aluminium guide structure and the vacuum tubing diameter is larger, to make full use of the broader CCD detector. The new bearing concept leads to improvements in use and the spectrometer works well.

Since the girder mover support was out of the scope of this upgrade, it remains a weak point when considering vibrations. However, the specified camera stability below 2 microns is easily surpassed with RMS displacement amplitudes around 100 nm. Furthermore, the amplification ratio from camera to girder, especially in transversal direction, is much lower than before the upgrade, manifesting the stiff structure and improved stability of the new camera support.

The improvements in the spectrometer prove effective and could well be used as base for a longer spectrometer arm in future development.

ACKNOWLEDGEMENT

We want to thank Markus Kropf, the workshop and the controls systems crew for their support.

REFERENCES

[1] G. Ghiringhelli *et al.*, “SAXES, a high resolution spectrometer for resonant x-ray emission in the 400 – 1600 eV energy range”, *Rev. Sci. Instrum.*, vol. 77, no. 11, p. 113108, Oct. 2006.