ISBN: 978-3-95450-250-9 ISSN: 2673-5520 doi:10.18429/JACoW-MEDSI2023-WEPPP016

MECHANICAL DESIGN OF XRS AND RIXS MULTI-FUNCTIONAL SPECTROMETER AT THE HIGH ENERGY PHOTON SOURCE

Jiuchang Zhang, Yujun Zhang, Zina Ou, Ruzhen Xu, Zhiying Guo, Shuoxue Jin, Xun Jia, Shanzhi Tang, Weifan Sheng, Wei Xu
Beijing Synchrotron Radiation Facility and High Energy Photon Source, Institute of High Energy Physics (IHEP), Chinese Academy of Sciences, Beijing, China

Abstract

The integration of an X-ray Raman spectroscopy (XRS) spectrometer and a Resonant Inelastic X-ray scattering (RIXS) spectrometer at HEPS is described. The XRS has 6 regular modular groups and 1 high resolution modular group. In total 90 pieces of spherically bent analyzer crystals are mounted in low vacuum chambers with pressure lower than 100 Pa. On the other hand, the RIXS spectrometer possesses one spherically bent analyzer crystal configured in Rowland geometry whose diameter is changeable from 1 m to 2 m. The scattering X-ray photons transport mostly in helium chamber to reduce absorption by air. The RIXS and the high resolution module can be exchanged when needed. Six air feet are set under the granite plate to unload the weight when the heavy spectrometer is aligned. The natural frequency and statics of the main granite rack were analyzed and optimized to maintain high stability for the HEPS-ID33 beamline at the 4th generation source. A type of compact and cost-effective adjustment gadget for the crystals was designed and fabricated. Economic solutions in selection of motors and sensors and other aspects were adopted for building the large spectrometer like this.

INTRODUCTION

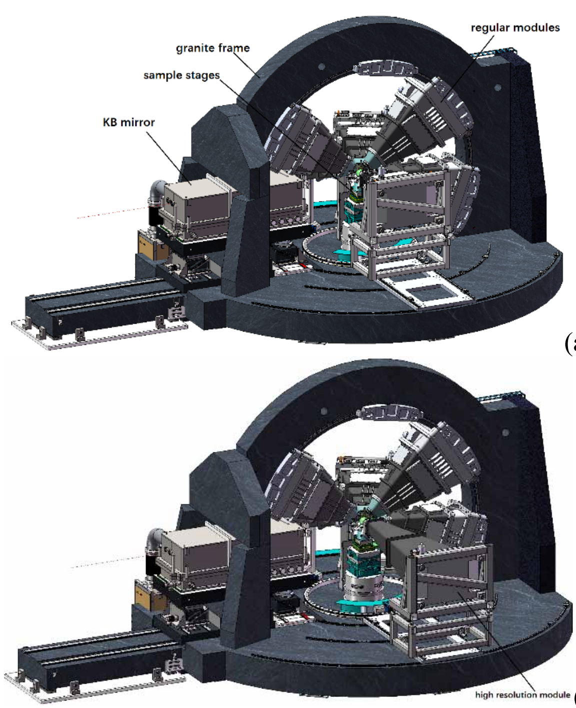
The inelastic X-ray scattering spectroscopy in the hard X-ray(>6 keV) regime is an indispensable tool for studying electronic excitations in condensed matter physics. The incident energy can either be in resonance with the binding energy of core-levels, or near the backscattering energy of crystal optics. The former is called resonant inelastic X-ray scattering (RIXS) and the latter is non-resonant inelastic X-ray scattering (NRIXS), also known as X-ray Raman scattering (XRS). To perform RIXS [1] and XRS [2], an energy-analysis spectrometer should be employed. More strictly, the RIXS also requires momentum-analysis, e.g. for studying the dispersion of magnons. Instrumentally, the spectrometers for both techniques are in common, based on the principles of Rowland circle, on which the sample, crystal analyzers and detectors are strictly aligned. Nevertheless, the RIXS spectrometer should sweep over the region of interest in the energy spectrum of scattered energy; while the XRS spectrometer can be static during data acquisition, in so-called “inverse scanning geometry” mode.

The ID33 beamline at High Energy Photon Source is the first beamline dedicated to inelastic X-ray scattering at HEPS. As is designed, the XRS and RIXS techniques will be operated in the same experimental hutch. To be cost-effective, it is reasonable to share the same focusing mirrors and sample stages. In this contribution, we will describe the mechanical design of the spectrometers and the concept for integrated spectrometer for beamlines targeting RIXS and XRS techniques together.

Integration of XRS and RIXS

This spectrometer integrates two functions, an X-ray Raman spectroscopy (XRS) spectrometer and a Resonant Inelastic X-ray scattering (RIXS) spectrometer, on one site, running separately at different time periods as needed.

The XRS has 6 regular modules and 1 high resolution module as planned. Each of them has a low vacuum chamber with pressure lower than 100Pa. A total of 90 pieces of spherical bent analyzer crystals evenly distributed across six chambers. Three modules rotate around sample point in vertical sliding on an arch bridge with a range -35°～163°. Other modules rotate around sample point in horizontal sliding on a base board and are separated by the vertical group on the bridge. The base board has two semicircles with different radii. The larger radius half supports the high-resolution module as well as regular. The XRS is showed in Fig. 1 below.



(a) (b)

Figure 1: a) XRS with a regular resolution module; b) XRS with a high energy resolution module.

ISBN: 978-3-95450-250-9 ISSN: 2673-5520 doi:10.18429/JACoW-MEDSI2023-WEPPP016

The RIXS is also on the larger half side. It can be exchanged by the high-resolution module. It possesses one spherically bent analyzer crystal configured in Rowland geometry whose diameter is changeable from 1m to 2m. The scattering X-ray photons transport mostly in helium chamber to reduce absorption by air. The RIXS is showed in Fig. 2 below.

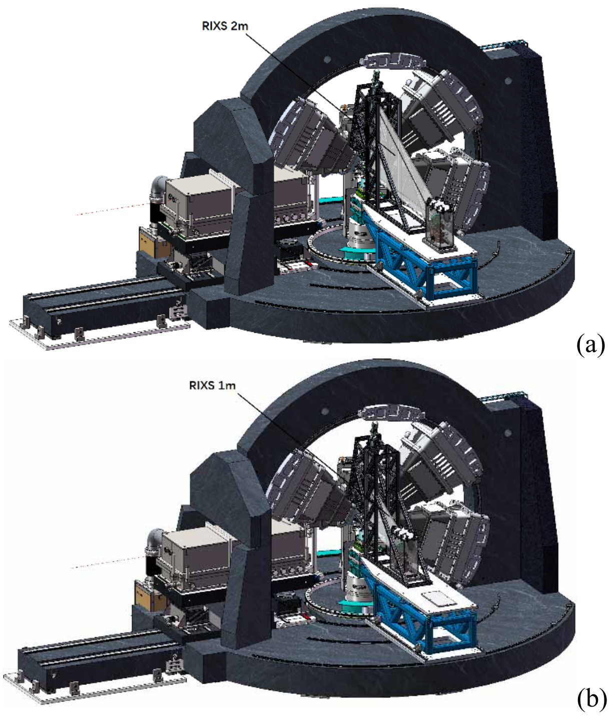


Figure 2: a) RIXS with 2 m Rowland circle; b): RIXS with 1 m Rowland circle.

Module chambers are made of aluminium. Fifteen analyzer crystals are mounted as a 3×5 array in every chamber. As shown in Fig. 3.

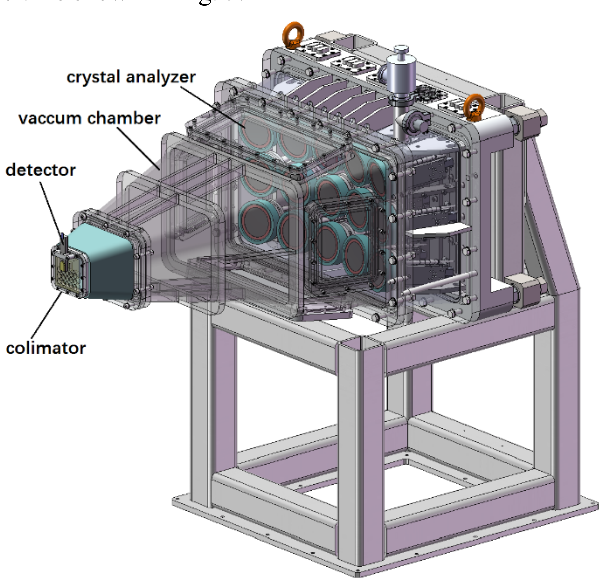


Figure 3: Regular module.

Main Frame

The main frame of the spectrometer is made of granite. The natural frequency and statics of the main granite frame were analyzed and optimized to maintain high stability. According to the measurement of ground vibration, it needed to Increase natural frequency of the frame as highly as possible. The final result is about 44 Hz, as shown in Fig. 4., a) and b) below.

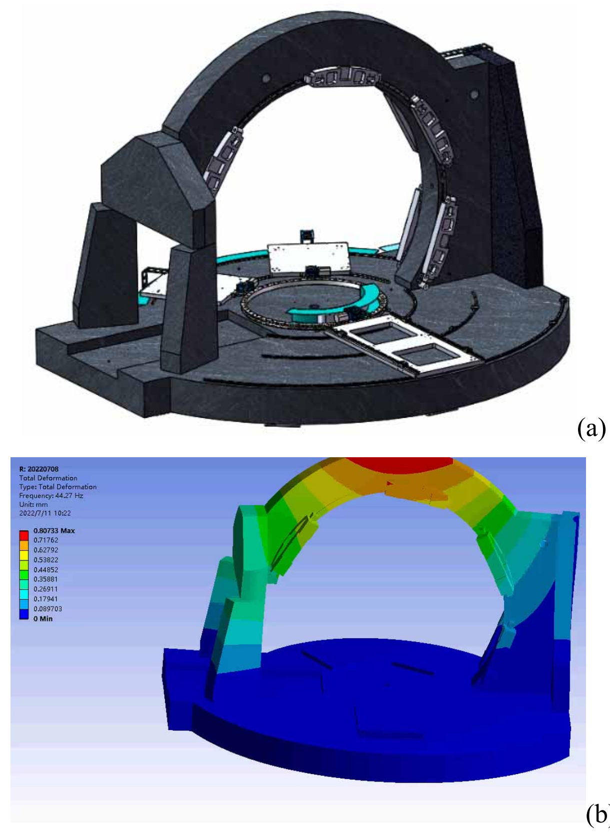


Figure 4: a) Final frame; b): Natural frequency analysis.

Its total weight is up to 20 tons. Six air feet are set under the granite plate to unload the weight when the heavy spectrometer is aligned finely. Other than these feet, there are several ordinary wedge pad under the base board to support the spectrometer.

Compact and Cost-effective Adjustment Gadget

Analyzer crystals need to adjust at three dimensions, two angles and one translation (Θ, c and a translation along the incident beam direction, tx). Every crystal is in a circular box with a aperture facing the sample and detector. The box can be mounted or removed easily and quickly shown as Fig. 5.

ISBN: 978-3-95450-250-9 ISSN: 2673-5520 doi:10.18429/JACoW-MEDSI2023-WEPPP016

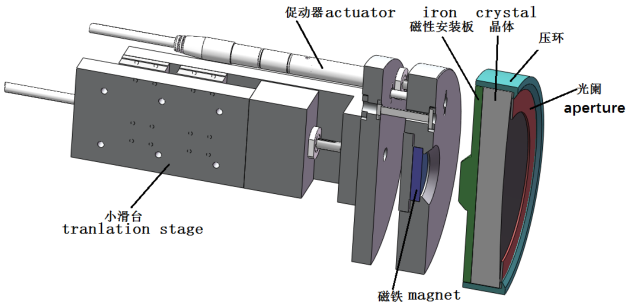


Figure 5: Compact and cost-effective adjustment gadget.

Status and Outlook

The granite frame has been made and is being assembled, as shown in Fig. 6.a). Fifteen analyzer crystal gadgets and one module chamber have been made and tested on one end station in BSRF. Results are satisfied, as shown in Fig. 6 below.


(a)

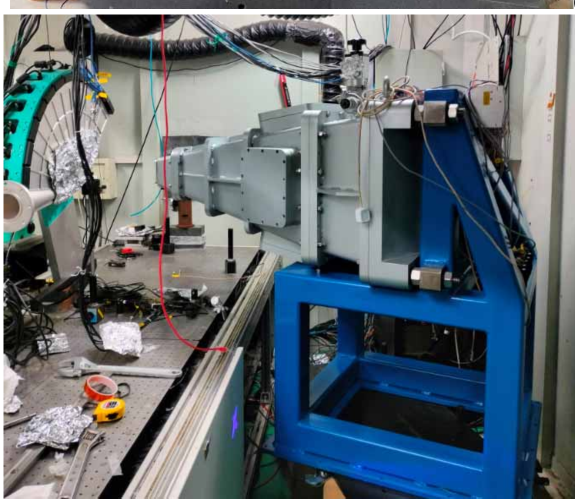

(b)

Figure 6: a) The granite frame picture; b): Module picture.

CONCLUSION

The multi-functional spectrometer for RIXS and XRS techniques at High Energy Photon Source (HEPS) are described. The granite structure is optimized both to reach a reasonably high natural frequency and to be manufacturable for practical reasons.

There are several advantages for this new design. Firstly, the flexibility of the modular design allows transformer-like combination of spectrometers for different scientific objectives. Secondly, this design is highly cost-effective; hence most of the concept also allows for testing or commissioning new-concept spectrometers at a reasonably low cost in the future. The project is still ongoing, the performance of the spectrometer will be tested at the beamline ID33 once HEPS is running.

ACKNOWLEDGEMENTS

The This work was supported by the High Energy Photon Source (HEPS), a major national science and technology infrastructure in China. We are inspired by various spectrometers in the world, like ESRF ID20, PETRA III P01, APS ID20, SPring-8 BL12XU, etc. We are indebted to fruitful discussions with S. Huotari, M. Sundermann, G.T. Seidler, C. Sahle, J. Ablett, Y. Cai, E. Alp, A. Baron, T.C.Weng, S. Zhang, Y. Ding, etc.

REFERENCES

[1] M. Moretti Sala *et al.*, “A high-energy-resolution resonant inelastic X-ray scattering spectrometer at ID20 of the European Synchrotron Radiation Facility”, *J. Synchrotron Radiat.*, vol. 25, pp. 580-591, 2018. doi:10.1107/S1600577518001200

[2] S. Huotari *et al.*, “A large-solid-angle X-ray Raman scattering spectrometer at ID20 of the European Synchrotron Radiation Facility”, *J. Synchrotron Radiat.*, vol. 24, pp. 521-530, 2017. doi:10.1107/S1600577516020579