PHOTON SLITS PROTOTYPE FOR HIGH BEAM POWER USING ROTATIONAL MOTIONS

X. Liu, W. Cheng, A. Walters, L. Hudson, H. Patel Diamond Light Source, Didcot OX11 0DE UK

Abstract

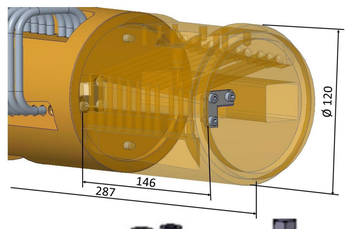
A new slits prototype utilising a rotatable oxygen-free high thermal conductivity (OFHC) copper block to absorb high heat load is developed for the Diamond-II upgrade. The slits will be used at front end of Diamond I13 X-ray Imaging and Coherence beamline which has two canted beamline branches. Required by the beamline optics, the front end slits function as virtual sources for the 250 meters long beamline. Working for the dual beam geometry, these specialised slits can vary the size of one x-ray beam with rotational motions while allowing the second beam to pass through unaffected. The rotational operations of the slits are achieved by an innovative commercial flex pivot and a unique in-house designed pivoting flexure.

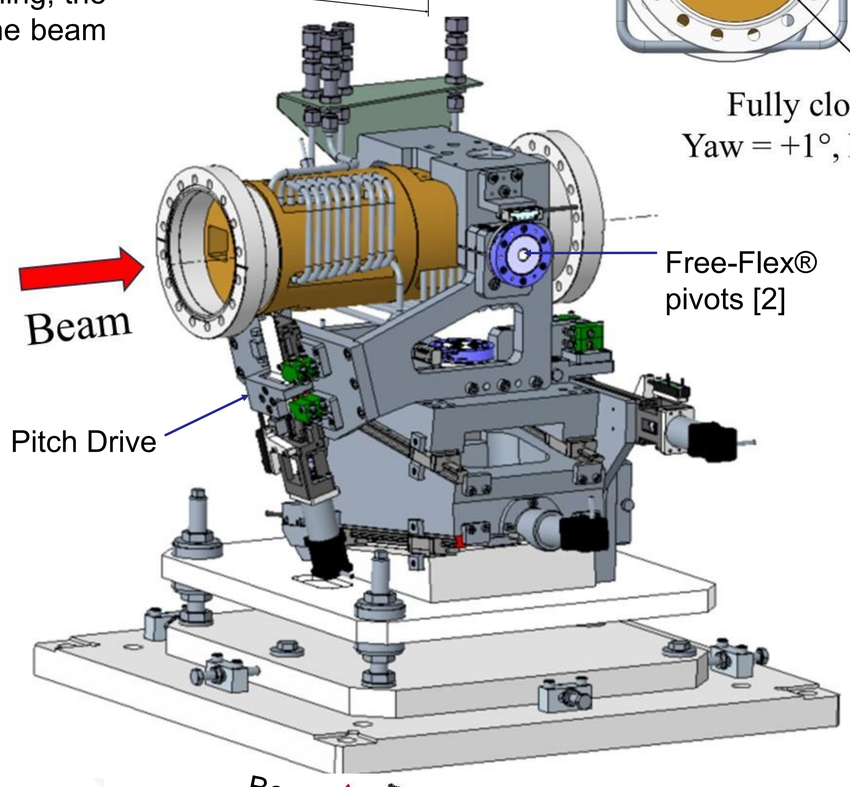
Design

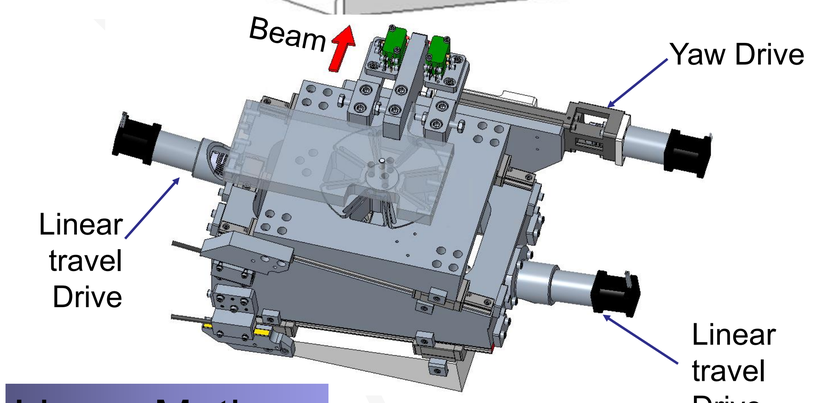
The slits are installed at 18.4 meters from the source. At the location, the photon beam size of the I13 Imaging branch is 4.1 x 4.1mm, and the beam size is 3.7 x 3.7mm for the Coherence branch. The slits vary the size of Imaging beam while allowing the Coherence beam to pass through unaffected. The slit is also required to scan the beam. When carrying out the scanning, the slits are opened a set amount and then driven across the beam in a vertical or horizontal motion.

In normal operation mode, slits are only required for varying opening apertures. Using the concept from Schmidt [1], the variation of slit aperture is achieved by rotating the slit block horizontally (yaw rotation) and vertically (pitch rotation). Pitch and yaw rotary stages are designed to control the slit width in the vertical and horizontal direction. The rotary stages are driven by a linear drive with the rotary motion produced by a flexure link between linear and rotary motion. Stiction-free and lubrication-free Free-Flex® pivots [2] are uniquely suited for the pitch rotary stages that have limited angular travel and use in a radioactive environment such as a front end. For yaw axis, we attempted a unique rotary flexure design.

OFHC Copper





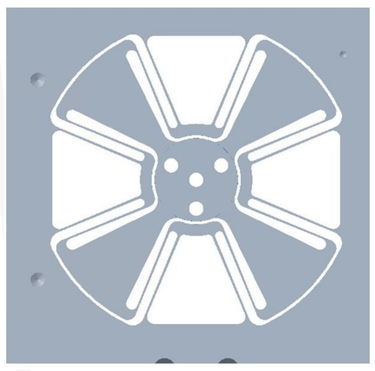


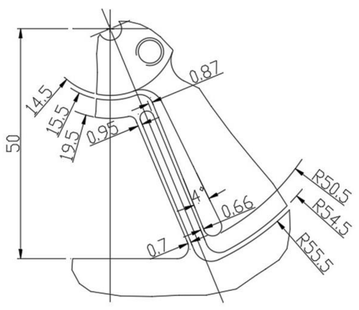
Linear Motion

A compound motion is needed to produce a purely horizontal or vertical motion. The scan distance is +/-4.5 mm at motion hard stops.

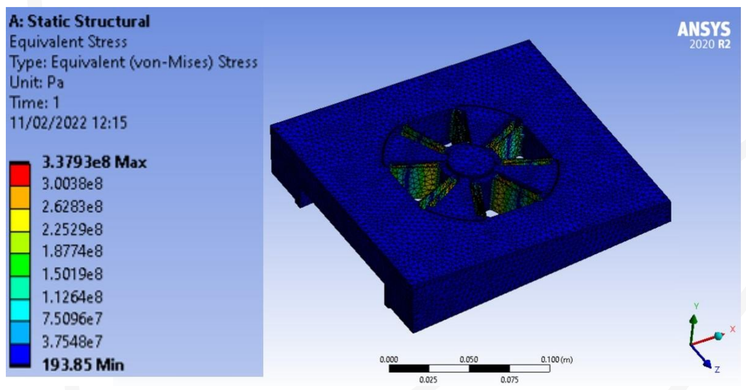
Yaw Rotary Flexure

The yaw rotary flexure uses a symmetrical leaf flexure design in the aim of the stiction-free and accurate rotation [3].



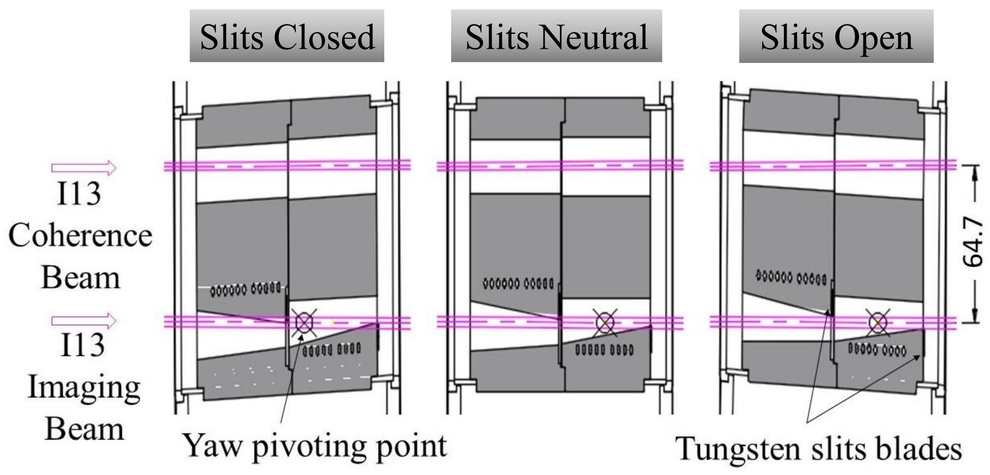


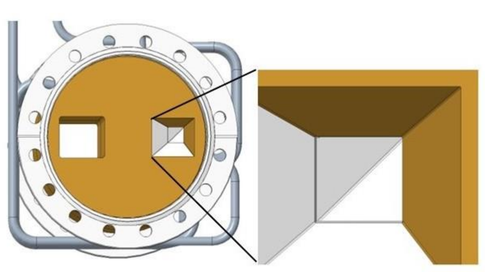
martensitic stainless-steel BS 970 420S45 heat treated to QT800 condition



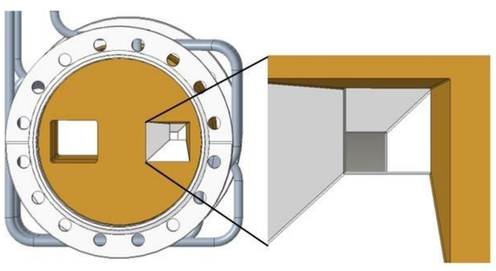
FEA was employed to optimise the thickness of the cross sections of the leaf flexure to give equal stresses along the length of the rib.

Dual Beam Geometry and the Slits Rotational Positions





Fully closed slits
Yaw = +1°, Pitch = +1°



Fully opened slits
Yaw = -1°, Pitch = -1°

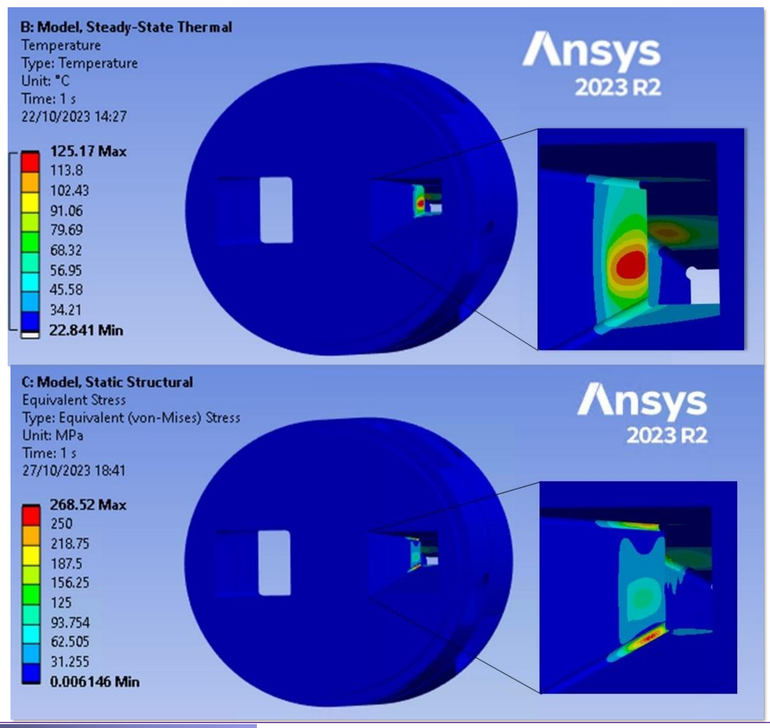
Thermal and Stress Analysis

Beam Power Data

Beam energy & current	3.5 GeV, 330 mA
Undulator U22	K: 1.8899
Total power at copper body	2.86 kW
Peak power density at 18.4 m	127.9 W/mm2

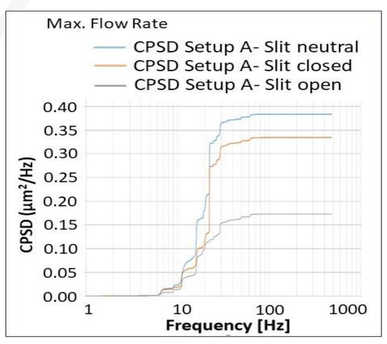
Diamond Elastic analysis criteria for OFHC:
T= 400 C°; σ_{eq}= 250 MPa [4]

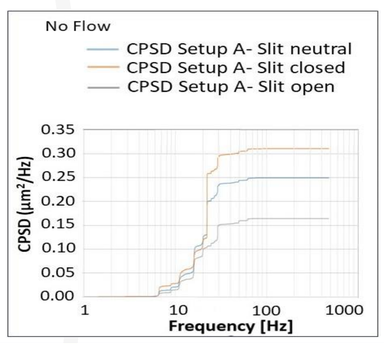
The peak thermal stress at the corner of the aperture is slightly higher than the limit for the elastic analysis. Further elastic-plastic analysis will be carried out.



Slits Stability

The slits was measured with laser vibrometer under vacuum and water pressure and flow close to operational conditions.





Conclusion

This prototype has validated the idea of using rotatable slits as a space saving solution for front ends. The initial vibration measurement confirms that the slits could be used as the beamline virtual source. It is promising that through geometry optimisation, rotatable slits using OFHC copper is feasible for high beam power applications. In our further endeavour, we will measure the slits in close to operational conditions with collimated light to explore the performance of the in-house designed rotary flexure.

Acknowledgements

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References

[1] O. Schmidt et al., “Variable aperture photon mask (slits) for canted undulator beamlines at the Advanced Photon Source”, in *Proc. MEDSI 2014 Conf.*, Melbourne, Australia Oct. 2014.

[2] Free-Flex® Pivots. http://www.flexpivots.com

[3] S. Wan and Q. Xu, “Design of a new rotational micropositioning mechanism driven by limited-angle torque motor”, in *Proc 10th IEEE Int. Conf. on Nano/Micro Engineered and Molecular Systems*, Xi'an, China, Apr. 2015, pp 209-213. doi:10.1109/NEMS.2015.7147412

[4] H. Huang et al., “Elasto-plastic analysis of heat absorbers in Diamond Light Source”, presented at the NWC Salzburg, Austria, June 2013.

For more information please contact X. Liu at xia.liu@diamond.ac.uk