Mechanical Design of a Soft X-ray Beam Position Monitor for the Coherent Soft X-ray Scattering Beamline

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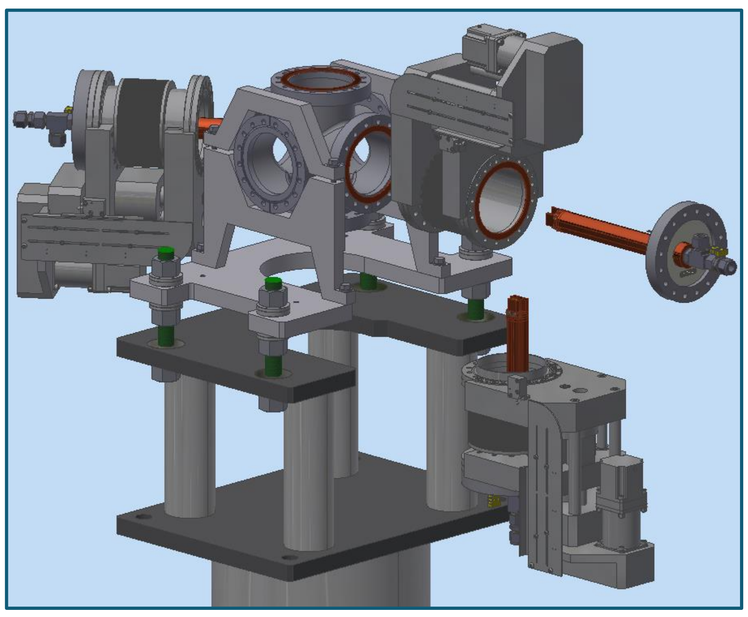
Abstract

Achieving photon beam stability, a critical property of modern synchrotron beamlines, requires a means of high resolution, non-invasive photon beam position measurement. While such measurement techniques exist for hard x-ray beamlines, they have yet to be achieved for soft x-ray beamlines. A new soft X-ray beam position monitor (SXBPM) design based on GaAs detector arrays is being developed and will be installed in the first optical enclosure of the Coherent Soft X-ray Scattering (CSX) canted beamline at the National Synchrotron Light Source II (NSLS-II).

The SXBPM assembly contains four water-cooled blade assemblies, each of which will have a GaAs detector assembly mounted within it, that can be inserted into the outer edges of the CSX undulator beam with sub-micron accuracy and resolution. The primary challenges in design of the SXBPM include: 1) mechanical stability of the assembly, 2) management of the heat load from the undulator x-ray beam to protect GaAs detector assemblies from unwanted illumination, 3) assembly compactness to fit within the first optical enclosure (FOE) of the CSX beamline, and 4) accessibility for modifications. Balancing the unique design requirements of the SXBPM along with their associated constraints has resulted in the design of a non-invasive beam position monitor which will be installed in the CSX FOE as a prototype for testing and iterative improvement. The ultimate goal is development of a widely useful SXBPM instrument for soft X-ray beamlines at high brightness synchrotron storage ring facilities worldwide.

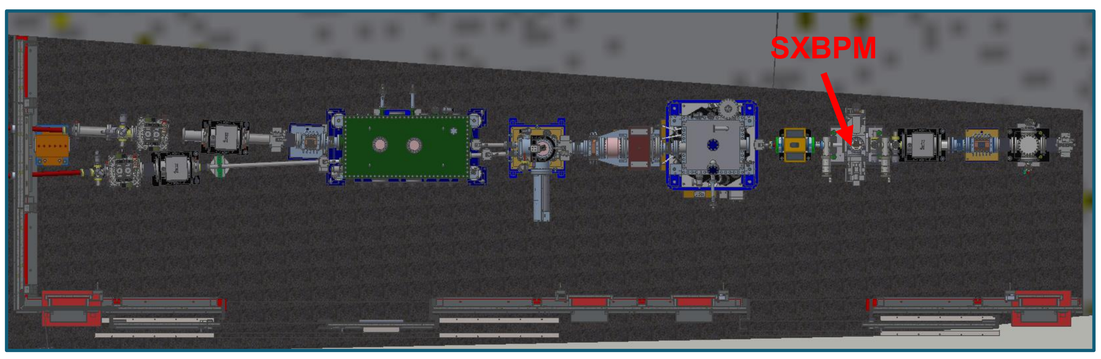
Stability and Resolution



With the SXBPM we aim to achieve micron-scale resolution X-ray beam position measurement and accuracy. This requires mechanical stability and detector positioning accuracy on the sub-micron level . The support stand consists of Invar 36 columns capped with steel plates. The BPM is mounted to a leveling plate on top of the stand.

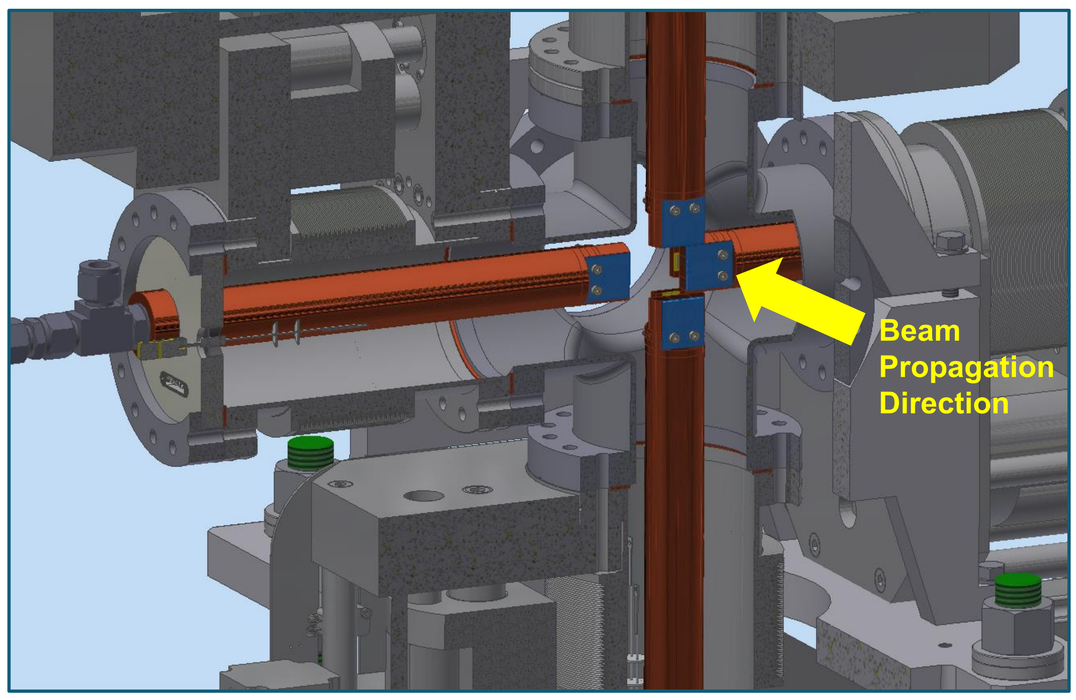
The SXBPM assembly has been designed so that each flange assembly should be removable from the vacuum vessel independent of the others to facilitate replacement and/or reconfiguration. Due to space constraints within the FOE and stability requirement, both the outboard and bottom flange assemblies must be removed along with the manipulator bellows on which they are mounted for replacement or reconfiguration.

The detectors are positioned by moving the entire flange assembly using a linear shift mechanism (LSM) instead of in-vacuum stages in order to avoid the use of in-vacuum water connections for routing water cooling through the copper heatsinks. Each flange assembly is mounted to a stepper motor driven linear shift mechanism (LSM) with absolute encoder to achieve submicron resolution. A travel range of 1” allows for the detector assemblies to be completely removed from the beam.



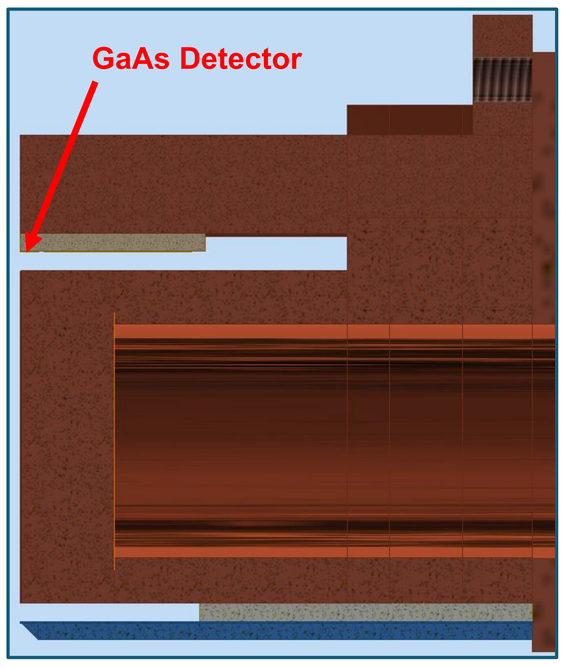
The SXBPM will be installed in the FOE to facilitate access and testing of the GaAs detector assemblies mounted within.

Modularity and Reconfiguration

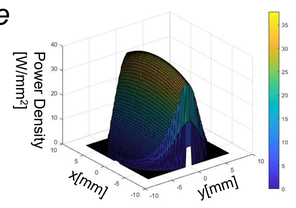


The SXBPM consists of four GaAs detector assemblies, each mounted on a copper heatsink. Two pairs of flange assemblies allow for the mounting of the detector assemblies to form vertical and horizontal pairs. The v-h configuration is shown above in which the vertical pair is positioned upstream of the horizontal pair. Reconfiguration to the h-v configuration can be done by removing and repositioning the flange assemblies.

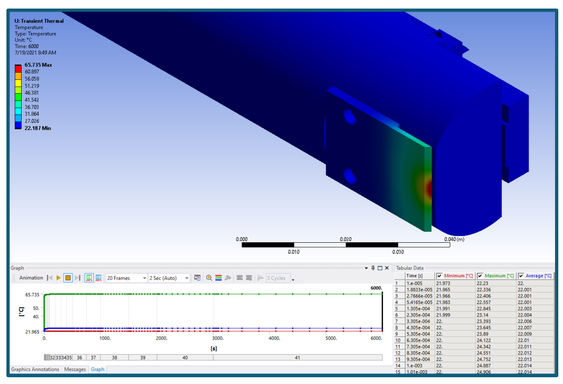
Heatsink Design

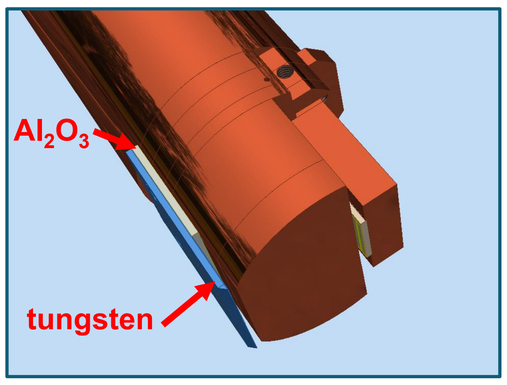


The beam profile of the “worst case” scenario with both undulators (K= 3.458).



The copper heatsink mounted on the flange assembly is designed to protect the GaAs detector assembly mounted behind it from heat buildup. Thermal analysis guided design using ANSYS Workbench has resulted in the inclusion of a removable tungsten aperture plate with an array of 30 μm diameter holes to allow enough of the beam to pass through to the detector array positioned downstream of the shield while preventing overheating of the detector unit behind it. The detector mounting will include a thermocouple to monitor the temperature of the tungsten plate and used with the Equipment Protection System (EPS) to withdraw the detector in case of beam obstruction. Design is dependent on several critical factors including maximum undulator K-parameter, area of intercepted beam profile, and location along the beamline.





References

[1] J. Liu, K. Kucharczyk, R. Lutchman, et. al. “Progress Towards Soft X-ray Beam Position Monitor Development”. IPAC 21. May 24-28th, 2021.

Acknowledgements

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