DESIGN OF VACUUM CHAMBER WITH CRYOGENIC COOLING OF SAMPLES

for Bragg-Plane Slope Error Measurements

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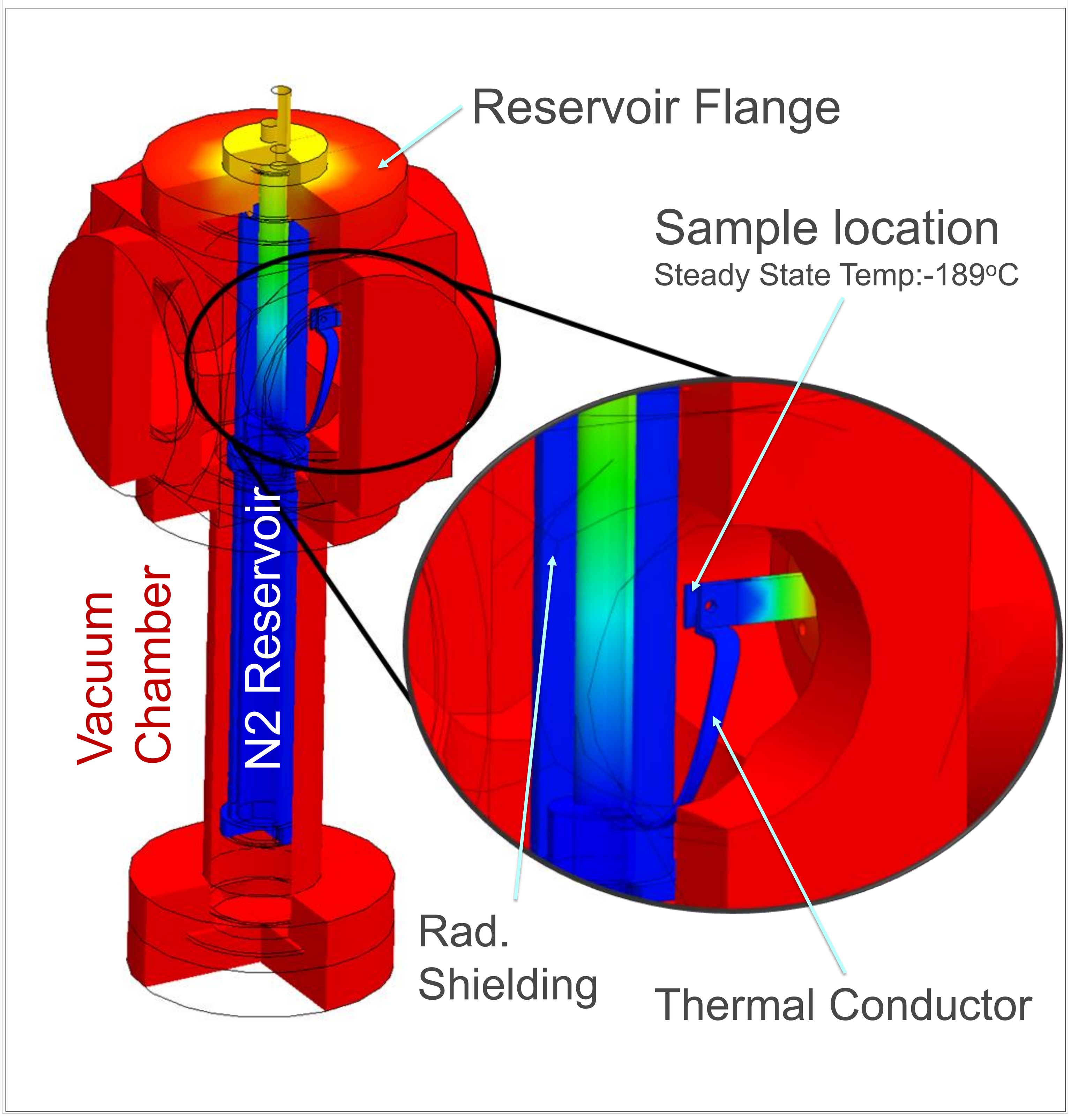
ABSTRACT

Wavefront preservation is essential for numerous X-ray science applications. Research is currently underway at the Advanced Photon Source to characterize and minimize Bragg-plane slope errors in diamond crystal optics [1]. Understanding the effect of cooling the optics to cryogenic temperatures on Bragg-plane slope errors is of interest to this research. Through the use of a finite element model a custom, compact vacuum chamber with liquid nitrogen cooling of samples was designed and is being manufactured. The design process and initial results are discussed with this poster.

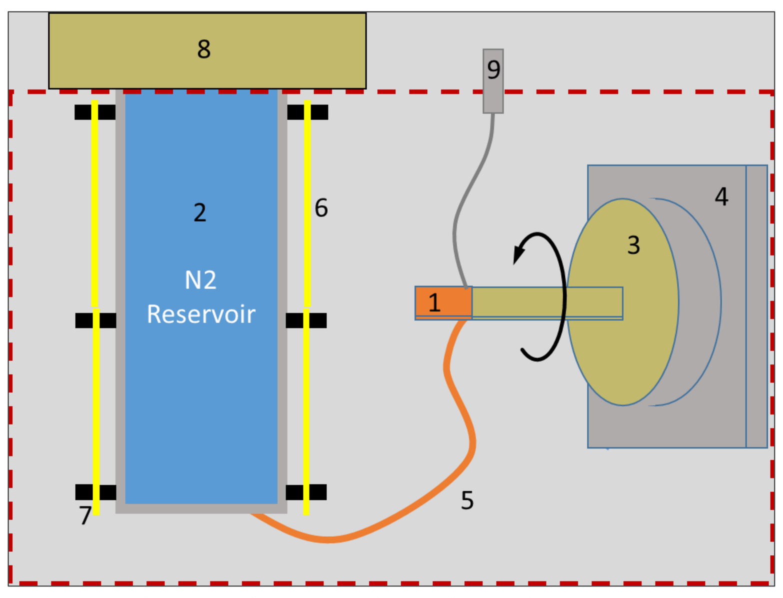
THERMAL FINITE ELEMENT ANALYSIS

- A Finite Element Model was created in SolidWorks® Simulation software and a Steady State Thermal analysis was run.
- Conduction and Radiation heat transfer were of primary concern for this analysis.
- Shell Elements were used for the N2 Reservoir, the Mylar Radiation Shielding, and a section of the vacuum chamber to reduce the overall number of elements in the model and thus the run time.
- At the sample location a steady state temperature of -189.1°C is predicted. It was estimated from the predicted power into the FE model and the latent heat of Liquid Nitrogen that this temperature (-189°C) would be constant for approx. 16 minutes.



DESIGN REQUIREMENTS

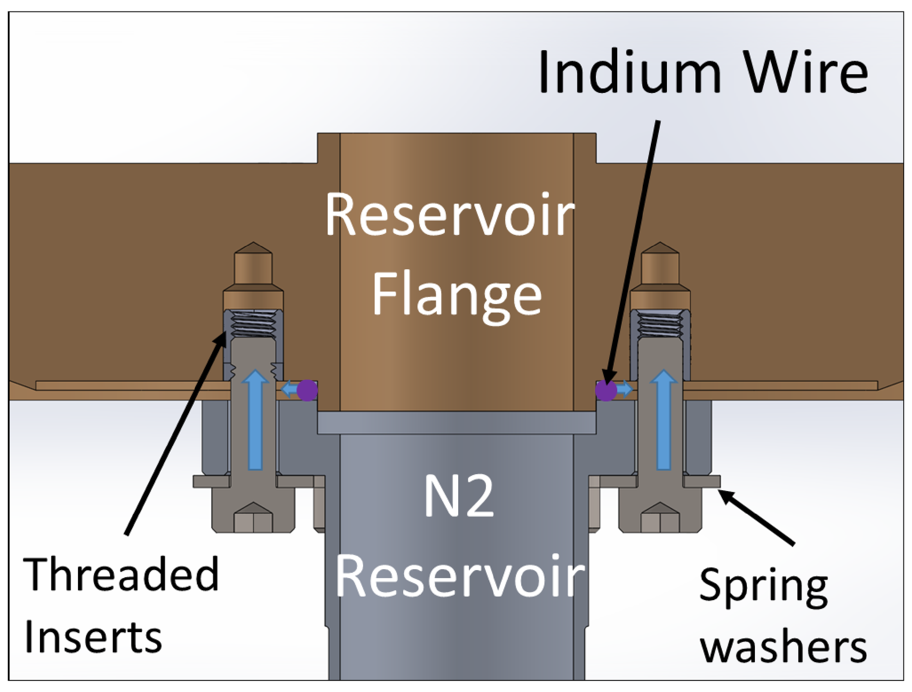
- Rotate crystal surface(1) ±45°
- Keep sample temp. < -150°C long enough to conduct X-ray experiment (approx. 30 min.)
- Operate in high-vacuum environment



1. Crystal Sample (Diamond)
2. N2 Reservoir
3. Crystal Mount (PEEK)
4. Rotation Stage
5. Thermal Conductor (OFHC)
6. Rad. Shielding (Mylar)
7. Spacer/Clamps (PEEK)
8. Reservoir Flange (PEEK)
9. Temp. Sensor (RT100)

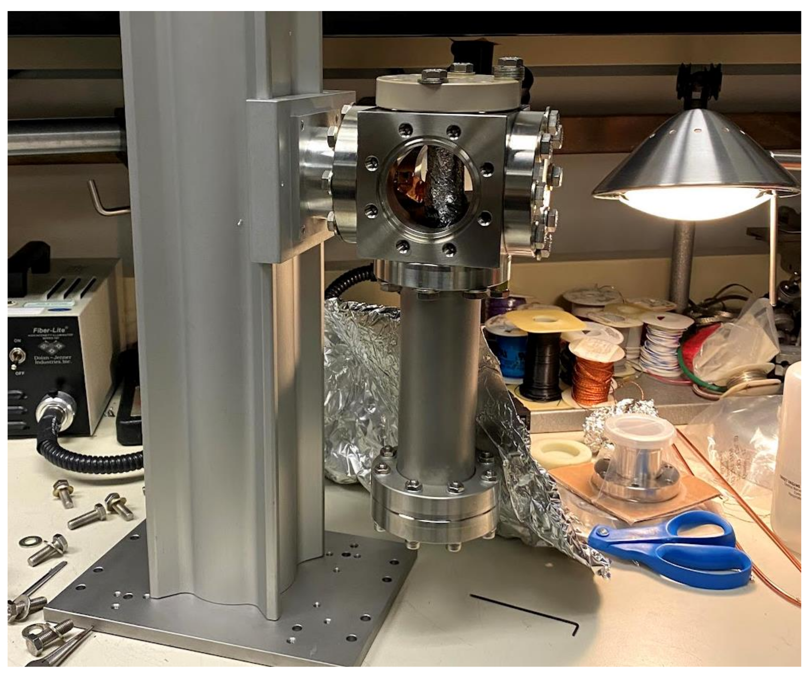
CHALLENGES

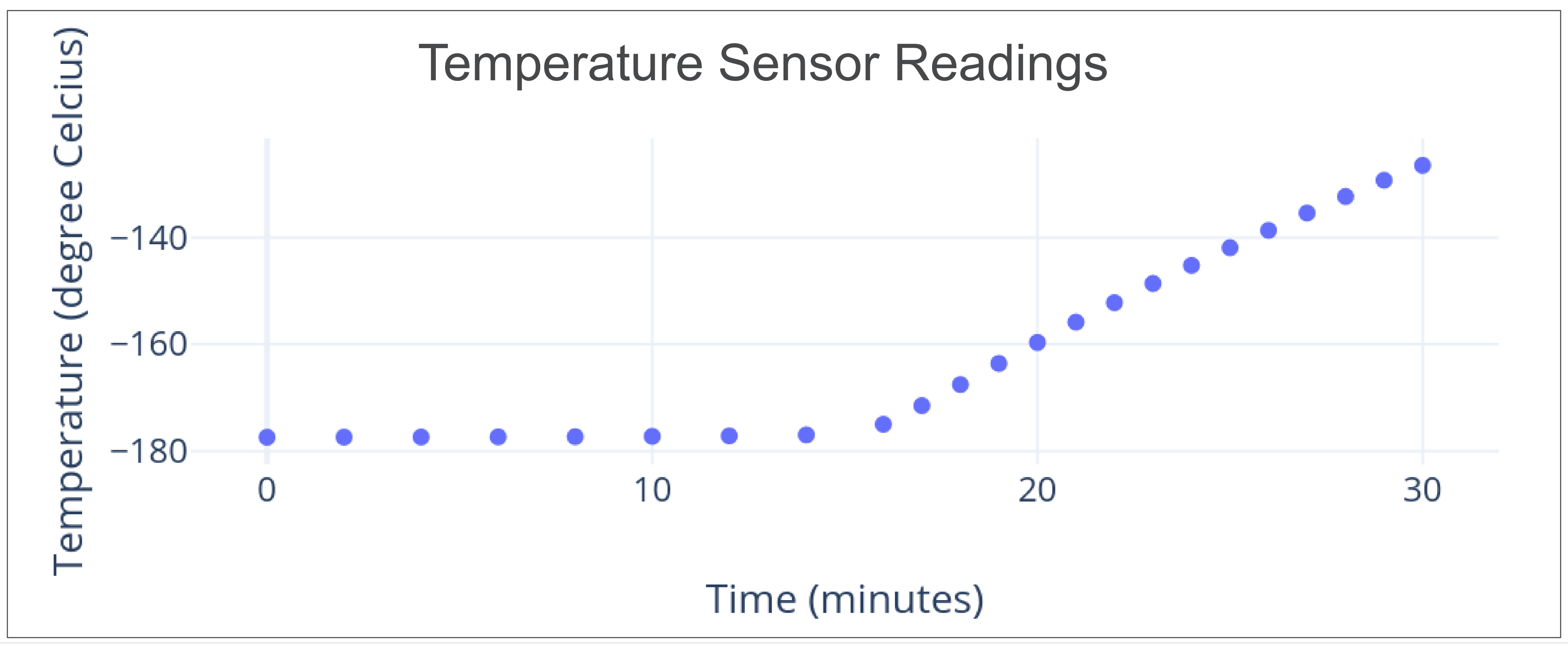
- Size: Compact and light as possible so it can be installed on current beamline stages
- Vacuum seal at cryogenic temperatures: Relatively large thermal *contraction* will happen between the N2 Reservoir (AL) and the Reservoir Flange (PEEK). A vacuum seal using an *indium wire* allows the seal to hold even at very low temperatures.



PROTOTYPE TESTING

- From the Finite Element Analysis results a prototype chamber was designed and built to test the cooling mechanism. An RT100 thermal sensor was fastened to the sample location to measure temperature.
- The Prototype Chamber test results were remarkably similar to the FEA. The sample location was cooled to about -180°C for about 15 minutes before starting to warm (the ~10°C discrepancy between FEA and Prototype results is due to the thermal conductor length needing to be extended for the prototype)





CONCLUSIONS

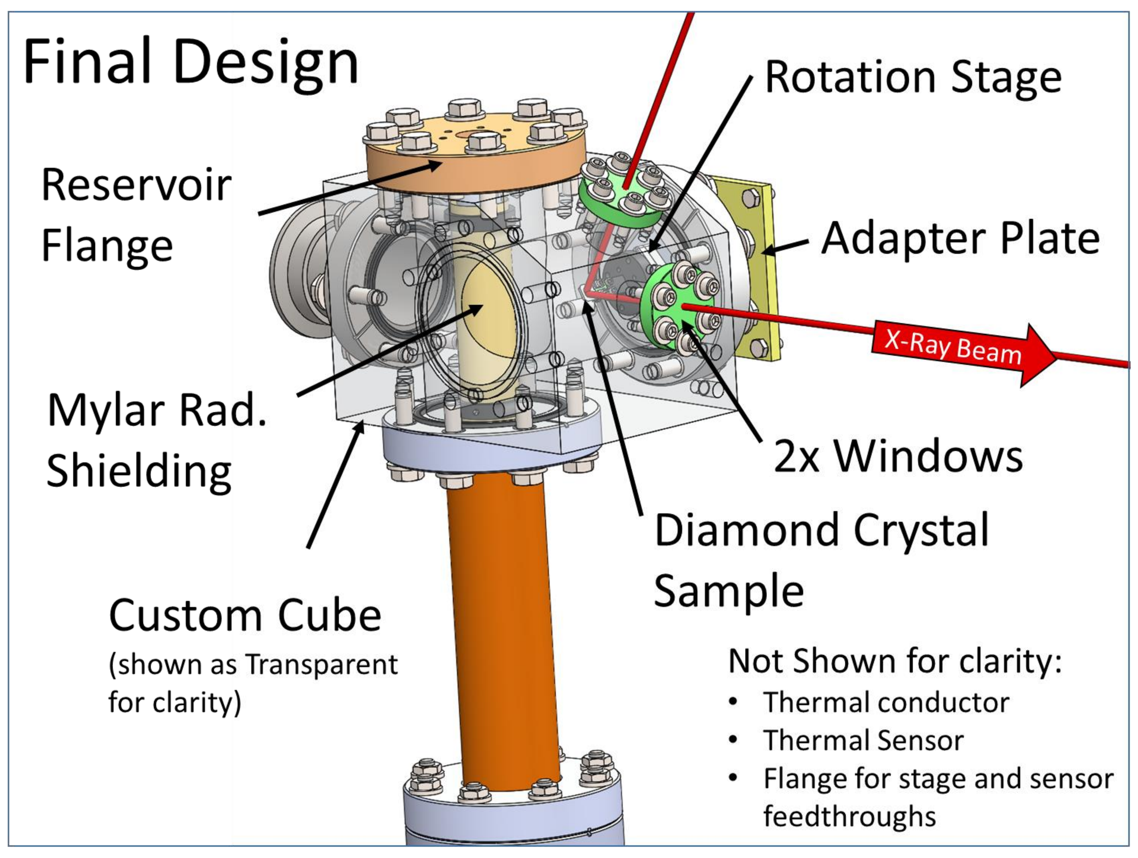
- Using finite element analysis a compact, [approx. 120 mm x 170 mm x 300 mm] cryo-cooling vacuum chamber was designed built and tested.
- The sample location was cooled to below -150°C for more than 20 minutes (This is shorter than design requirement it should still be acceptable)
- Utilizing an indium wire seal at low temperature joints high-vacuum was achieved

NEXT STEPS

- Complete Design Requirements: A final design for the chamber has been completed. The design includes a rotation stage and beryllium windows to allow the X-ray beam through to the sample. The final design is currently being manufactured.
- Complete Bragg-Plane slope error measurements at the beamline with X-rays.

REFERENCES

- [1] T. Sun, *et al.*, Nat. Photonics **6**, 586 (2012).
- [2] D. Shu, *et al.*, this conference.



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