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A NOVEL VACUUM CHAMBER DESIGN FOR THE APS UPGRADE OF THE 26-ID NANOPROBE

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Abstract

An enhancement design of an existing 26-ID nanoprobe [1] instrument (NPI) at APS is being completed as part of work for the APS-Upgrade (APS-U) project. As part of this enhancement design, a new vacuum chamber geometry configuration has been implemented that balances the desired simultaneous x-ray measurement methods with accessibility and serviceability of the nanoprobe. The main enabling feature on the vacuum chamber is a slanted mid-level vacuum sealing plane. The new chamber design geometrically optimizes the ability to perform simultaneous diffraction, fluorescence and optical or laser pump probe measurements on the sample. A large diffraction door geometry is strategically placed near the sample for ease of access. The newly designed chamber can be readily serviced by removal of the upper chamber section, on which most larger instrument assemblies or beamline attachments are not interfaced. The mechanical design intent and geometry of this chamber concept is described in this paper.

INTRODUCTION

The upgrade of the 26-ID NPI will enable the observation of samples with x-ray diffraction, flourescence, and photoluminescnce while also allowing for the abiility to manipulate the sample with laser or elecctrnic stimulation and its enviornemnt with heating and cooling. This combination of measuremnt and sample maniulation enables world class operando studies.

The scope and breadth of the science to be performed by the upgraded 26-ID NPI are enabled by several technologies. Area and florescence detectors and manipulations, vacuum design, widowing, nanopositioning mechanics [2], and high resolution optics all need to be thoughtfully integrated to create an effective nanoprobe. Although trivial in technical merit compared to the other aspects and technologies of the, the vacuum chamber geometry imposes fundamental limitation on measurement capability, flexibility, and adaptability of the instrument. The limitations that can come with a vacuum chamber design may present challenges to scientific staff that could detract from their mission.

The prior nanoprobe vacuum chamber had desirable features, such as a large diffraction window, cable management that is incorporated into a lower section of the chamber, and adequate space inside the chamber for routing wiring and accessing equipment. However, this prior iteration presented challenges for adding more modalities of measurement, and also has some non-ideal servicing steps, such as removing the x-ray fluorescence detector to take the upper portion of the chamber off.

To optimize the capabilities of the upgraded nanoprobe, the proposed vacuum chamber design incorporates a new angled sealing plane. The sealing plane is strategically positioned to enable simultaneous measurement techniques, while also balancing other serviceability and accessibility. For the upgrade door solution, inspiration was drawn from the existing NPI and the hard x-ray nanoprobe (HXN) at NSLS-II [3, 4]. An image of the entire new instrument is shown in Fig. 1.

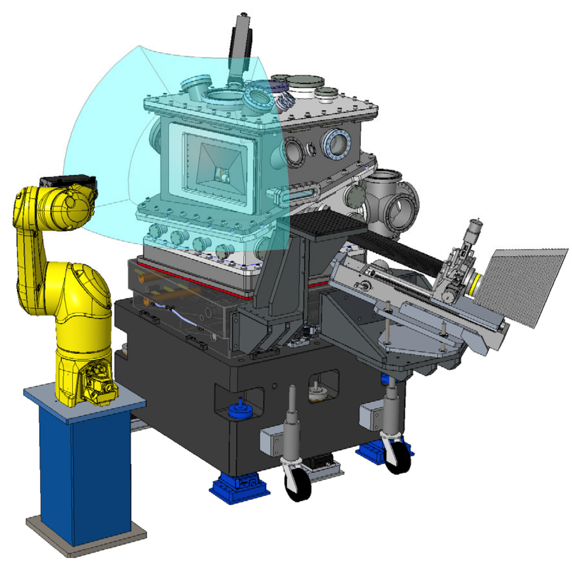

Figure 1: The new 26-ID nanoprobe enhancement as part of the advanced photon source upgrade.

NANOPROBE CONFIGURATION METHODOLOGY

The following numbered items represent the most critical requirements of design and configuration for this instrument:

1. The design must maximize the diffraction envelope downstream of the instrument for area detection over the original design.
2. A Be window must be used for the downstream window.
3. A wide-angle range (>25deg) for optical configurations or laser pump probe measurements must be implemented on the outboard side of the chamber in the horizontal sample plane.

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4. A fluorescence detector must be able to approach the sample. It is acceptable for this to approach the sample from below the horizontal plane.
5. The ability to have simultaneous diffraction, optical, and fluorescence detection should be implemented in the design.
6. The sample region must be accessible for exchange.
7. It is desirable to be able to service the instrument without having to remove the fluorescence detector, beamline connection, or wiring feedthrough for all internal components.

VACUUM CHAMBER DESIGN

In order to optimize the requirements, a slanted mid-level sealing plane is implemented. A render of the design can be seen in Fig. 2. The vacuum chamber is to be made of 304L stainless steel, with half inch wall and four inch base plate thicknesses. There are o-ring gaskets incorporated in each major chamber joint. Custom optical viewports are integrated to meet the needs of the optical and fluorescence measurements. A custom Be window and door design is on the downstream side of the chamber. The XRF detector, beamline connection, electrical feedthroughs, and turbo pump are all mounted to the lower chamber section below the slanted sealing plane. This allows for easier removal of the top chamber section.

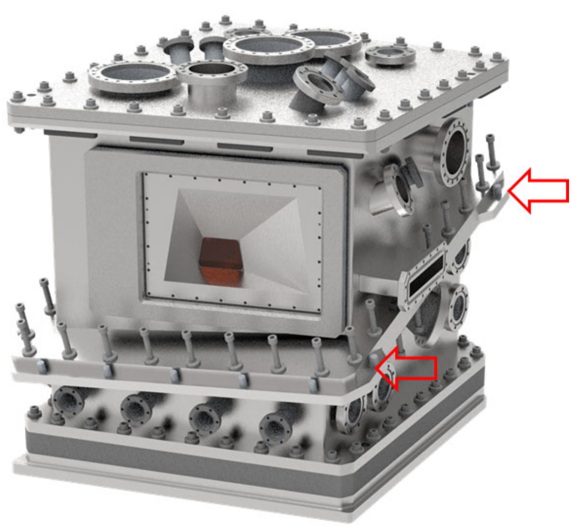

Figure 2: Rendering [5] of the nanprobe vacuum chamber design. The slanted mid sealing plane is pointed to in two locations upstream and downstream.

SIMULTANEOUS METHODS

Figures 3 and 4 depict how the simultaneous methods are achieved with the chamber design.

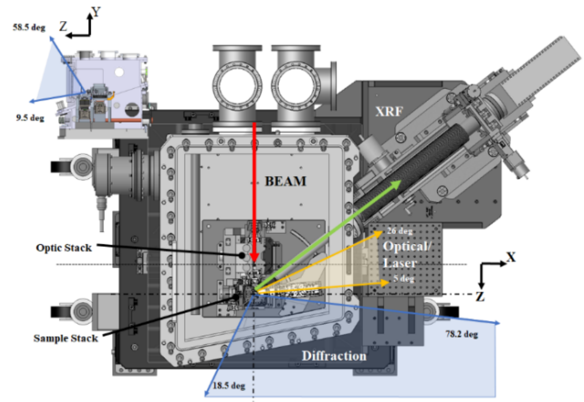

Figure 3: Schematic showing how the simultaneous methods of the NPI are carried out with cross section in the XZ plane. The flouresecnce detector is 18° below the XZ plane. The beam (red), diffraction range (blue), optical or laser (gold), and floursecnce (green).

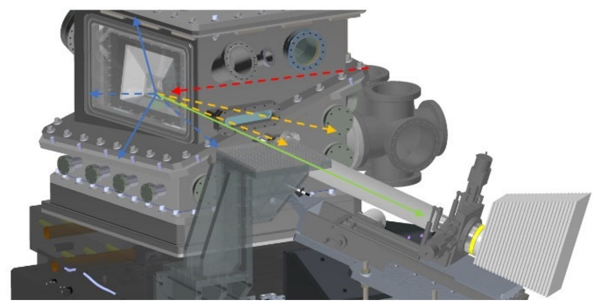

Figure 4: Schematic showing how the simultaneous methods of the NPI are carried out. The flouresecnce detector is 18° below the XZ plane. The beam (red), diffraction range (blue), optical or laser (gold), and floursecnce (green).

Be WINDOW UPGRADE

The beryllium window is a cartridge brazed design that gets brazed into a weldment. The Be window design is depicted in Fig. 5. The weldment is mounted on the downstream chamber door onto an O-ring joint. The Be window design was made to have higher angular diffraction range than the historic design using less area by carefully choosing its proximity to the sample. The door feature allows for ease of sample or optic change.

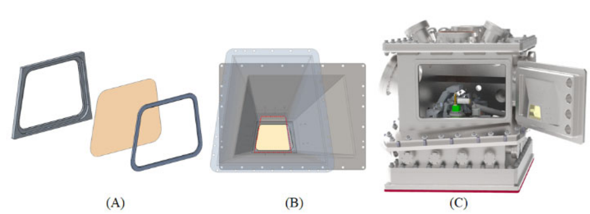

Figure 5: Schematic showing the beryllium window (A), The old (blue transparent) and new (gray) NPI window welment design (B), and the open door of the NPI with the beryillumn weldment loaded (C).

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ACCESIBILITY

In addition to the door of the prior section, the new chamber was designed to allow for accessibility to service items when the upper chamber is removed. The slanting of the sealing plane allows for more access to internal components. This is depicted in Fig. 6, along with the modular instrumentation bench that can be removed.

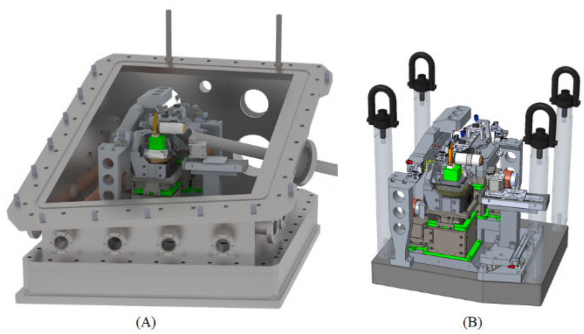

Figure 6: Schematic showing the NPI chamber with the upper portion removed (A) and the modular instrumentation bench that can be removed (B).

VACUUM CHAMBER FEA

FEA [6] was performed to determine sufficient stresses in the chamber concept. The results are shown in Fig. 7. Displacements are also used to inform design tradeoffs. A thicker base plate reduces the shifting of internal components when going from atmosphere to vacuum.

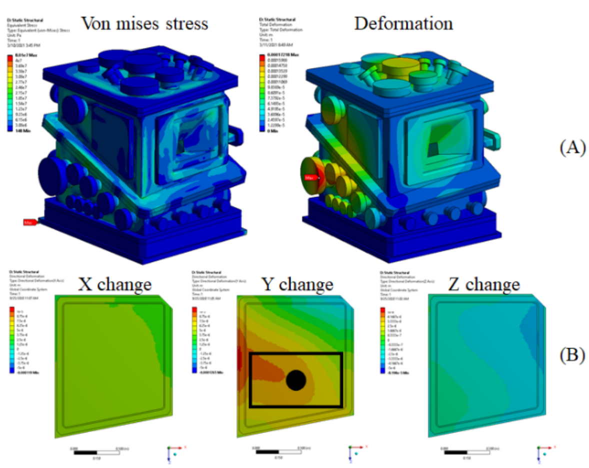

Figure 7: FEA Results. Stress and deformation of the chamber (A) and the base plate deformation (B). These results were used to inform design decisions, including the shifiting of components mounted to the chamber externally or internally.

CONCLUSIONS

The novel slanted sealing plane vacuum chamber design meets the multimodality requirements of this instrument while also enabling accessibility, serviceability, and forward looking flexibility.

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