PROGRESS OF NANO-POSITIONING DESIGN FOR THE COHERENT SURFACE SCATTERING IMAGING INSTRUMENT

for the Advanced Photon Source Upgrade Project

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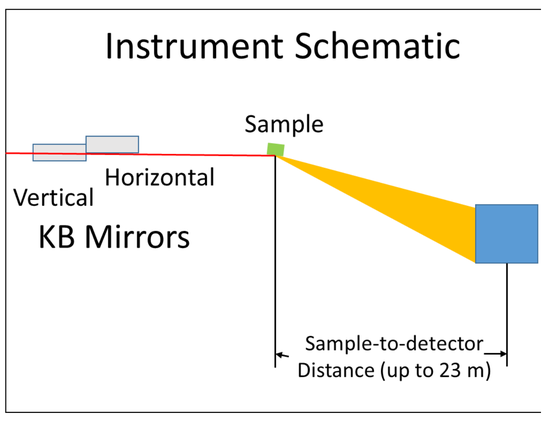
ABSTRACT

As part of the Advanced Photon Source Upgrade (APS-U) project, the Coherent Surface Scattering Imaging (CSSI) [1] instrument is currently being developed. One of the most important components of the CSSI instrument at the 9-ID beamline of the APS-U, the Kirkpatrick-Baez (K-B) mirror system, will focus hard X-rays to a *diffraction-limited* size of 500 nanometers at a working distance of 550 mm. High angular stability (19 nrad for the horizontal mirror and 14 nrad for the vertical mirror) is specified not just for the focused beamsize but, more importantly, to ensure the beam stability at the detector position that is up to 24 m from the K-B mirrors. A large sample-to-detector distance (up to 23 m), one of the beamline's unique features for achieving a sufficient coherent-imaging spatial oversampling, requires sample angular stability of 50 nrad. In CSSI scattering geometry, the vertically placed sample reflects X-rays in the horizontal direction at an extremely shallow angle. The design includes two high-precision rotary stages for sample pitch (vertical axis) and yaw (horizontal axis). The current design of instrument's nano-positioning stages [2] and metrology required to satisfy the stability and positioning requirements are discussed in this poster.

MOTIVATION

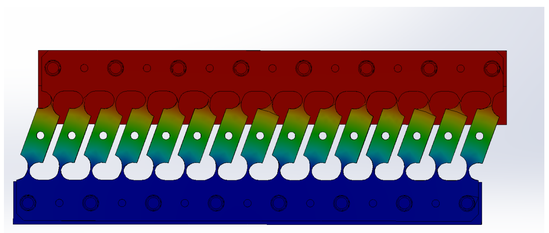
- Use coherent scattering for non-destructive,in-situ structure characterization with high three-dimensional resolution and high temporal resolution
- Large Sample to detector distance(up to 23m) to achieve speckle oversampling



METHODS

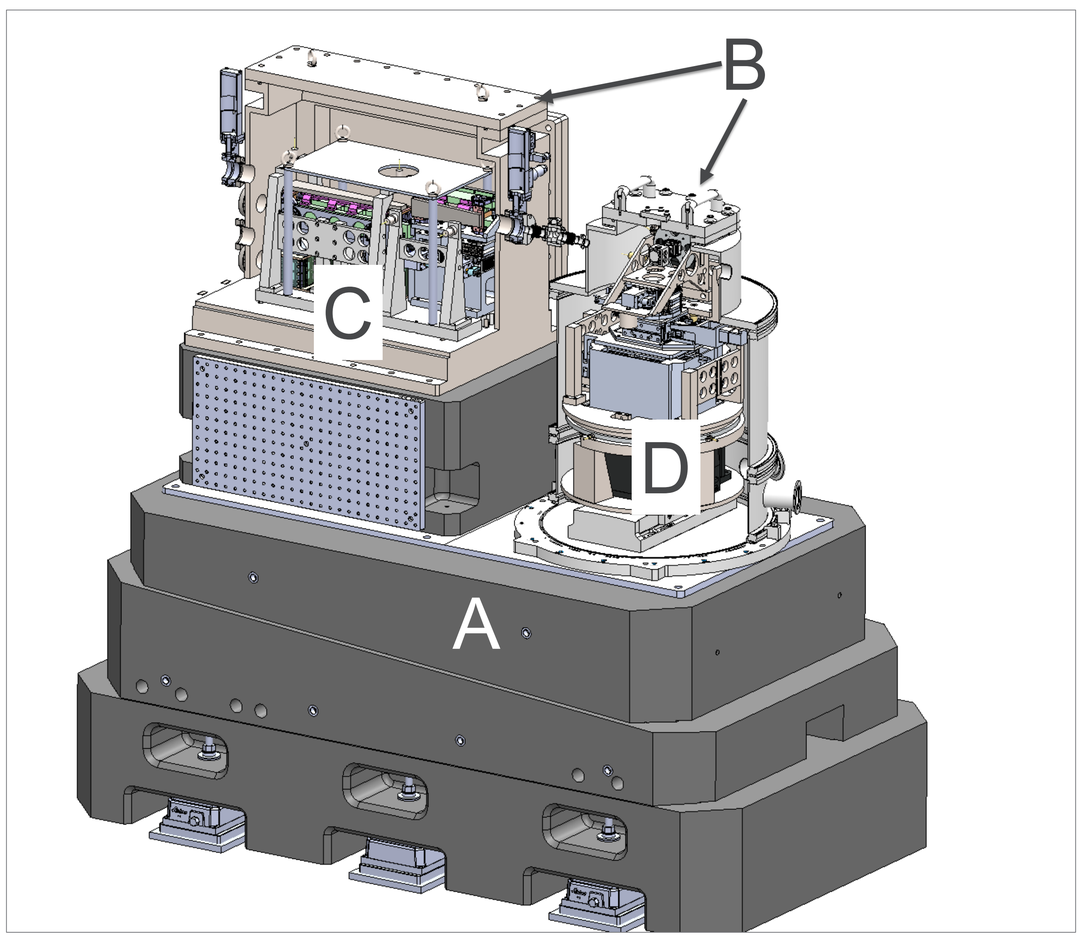
- Weak-link laminar flexures are used to overcome limitations of ball-/cross-roller bearing stages
- Three (3) different 6 channel metrology frames using capacitive sensors and laser interferometers to achieve positioning and stability requirements.

Weak-link Motion



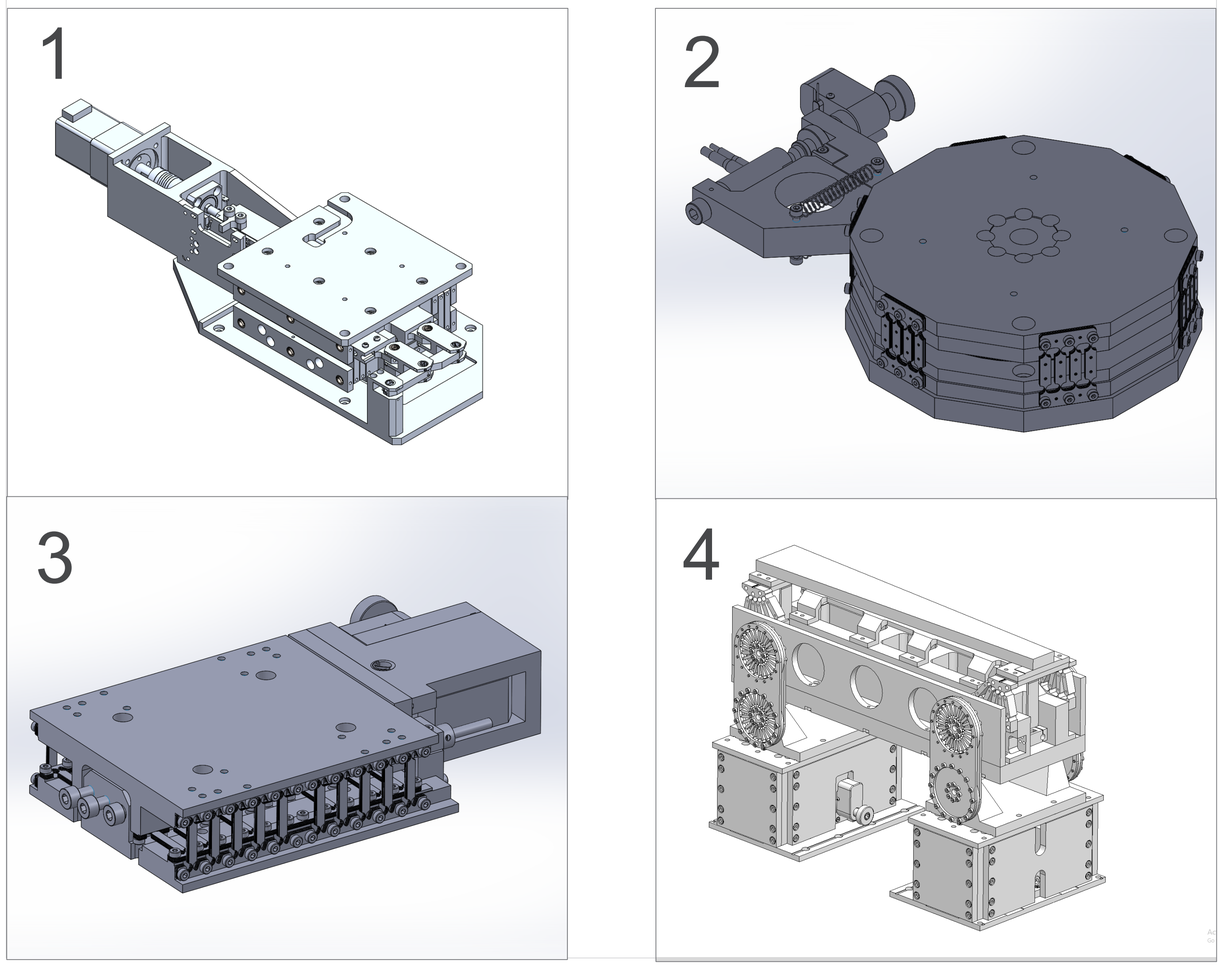
INSTRUMENT LAYOUT

- CSSI Instrument Features:
  A. Granite air-bearing stages for aligning KB mirrors and sample to the Beam
  B. Vacuum Chambers (KB mirrors: UHV, Sample HV)
  C. Kirkpatrick–Baez mirrors with alignment apparatuses and laser interferometer metrology.
  D. Sample stages (custom flexure and mechanical bearing stages) and metrology frames



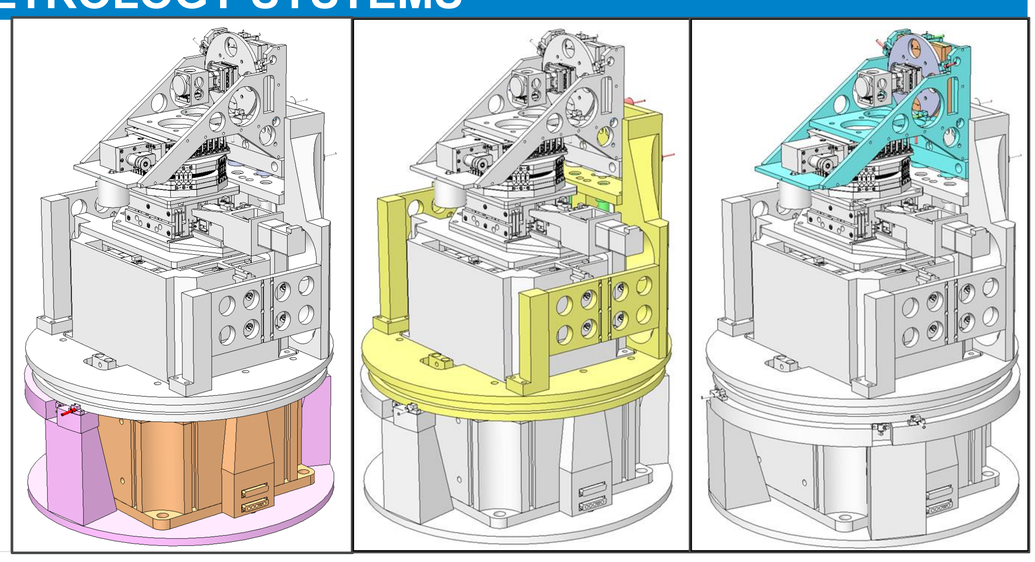
FLEXURE STAGES

1. T8-56: Flexure bearing stage with centimeter-level travel range with nanometer minimum incremental motion (MIM) [3]
2. T7-52: Corrects sample pitch with a travel range < 1° and MIM of tens of nano-radians [2]
3. T8-48 Horizontal Stage: Piezo driven flexure stage with travel range of 1 mm and nanometer-level MIM [4]
4. Bendable KB mirror with nano-positioning alignment apparatus [2]



SAMPLE METROLOGY SYSTEMS

- The rotation metrology (shown in purple and blue) use six (6) channels *each* of capacitive sensors. The sensors are mounted to an Invar® frame and target a polished aluminum disc. By calibrating the system [5] axial and radial errors can be measured on the nanometer level and tilt errors in the 10s of nanoradians.
- The linear stage metrology (yellow) consists of an Invar® frame and six (6) collimated laser interferometers heads with mirrored targets. Linear errors measured at 10s of nanometers and angular errors to 100-200 nanoradians



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- [1] T. Sun, *et al.*, Nat. Photonics **6**, 586 (2012).
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