Design, installation and verification of

Mogno beamline nano station metrology system in LNLS/Sirius

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Abstract

The emergence of the 4th generation of synchrotron light sources made it possible to perform much faster and more precise experiments, requiring state-of-art beamlines and end-stations to deliver the necessary mechanical, thermal, and optical parameters. MOGNO [1] is a nano focus beamline at SIRIUS, the 4th generation synchrotron light source in Brazil, that uses a conical X-ray beam, focalized with a pair of KB mirrors to a 150nm x 150nm spot [2], to perform nano and microtomography. However, to fully exploit the capabilities of MOGNO's nano focus, maintaining precise sample position stability relative to the x-ray beam is of utmost importance in the end-station. Furthermore, accurate metrology of the sample position during the experiment plays a crucial role in unlocking the beamline's ultimate resolution by feeding reconstruction algorithms. This paper presents the design, installation, commissioning, and verification of a 5D position metrology system developed specifically for measuring the sample position and stability at MOGNO's nano-station. The paper will cover various aspects including dynamic and thermal design models and considerations, integration architecture, calibration techniques, using spindle error separation [3], and the verification method used in the metrology system. For that, we compare the results of a near-field Ptychography experiment performed at the beamline using the original and corrected positions obtained by metrology.

The MOGNO nano-station metrology system has been meticulously developed to meet specific requirements from the beamline. Crucially, the system is designed not to adversely affect the stability or operability of the end station when not in use. It boasts a resolution surpassing 10nm RMS, enabling the reconstruction of tomography with $100nm^3$ voxels. Furthermore, the system was designed to support experiments at frame acquisition rates from 200Hz up to 1kHz, the maximum for the MGN nano-station.

This paper delves into the design of the metrology system, discussing sensor types and arrangements as illustrated in Figure 1, dynamic modeling, thermal considerations, material selection, and culminating with the final mechanical design presented in Figure 2. Key elements crucial for meeting the beamline's requirements are emphasized throughout the discussion.

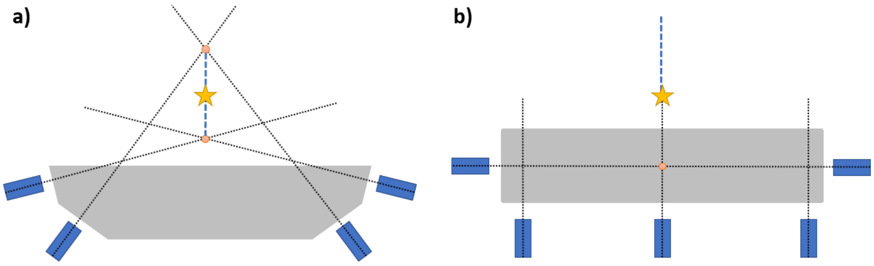

FIGURE 1: The two alternatives of sensor arrangement are considered for MOGNO's Nano-station metrology. a) Sensors in ABBE configuration using two-cone geometry. b) Sensors in the planar configuration, using a cylindrical target.

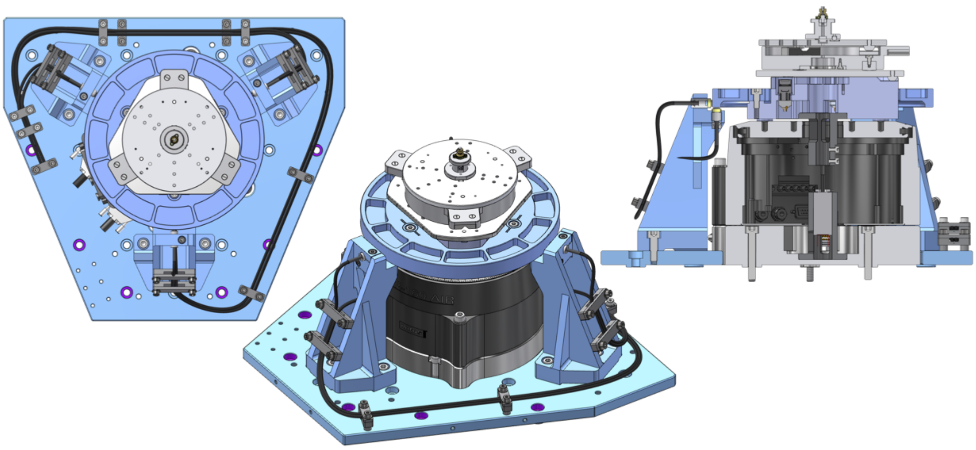

FIGURE 2: Final mechanical design for MOGNO's Nano-station metrology showing the metrology target, sensors support, sensor cable management and sample holder.

This paper also addresses the installation and commissioning of the metrology system, highlighting the mechanical alignment of the metrology target and sensors during final assembly, as depicted in Figure 3. A critical procedure of this phase is the calibration of the system to ensure optimal performance. We outline the application of the multiprobe spindle error separation technique, which allows for the decomposition of metrology measurements (Figure 4) into synchronous and asynchronous errors stemming from the goniometer and target surface finishing. Additionally, we discuss the electronic architecture for data transmission and software considerations necessary to integrate metrology data into the tomography workflow for post-processing.

The metrology system will be validated with the comparison of tomography reconstruction results of standard test samples with original e metrology-corrected positions from the experiment scan. The expected improvement will not only increase the resolution of the images provided at Mogno but also simplify the processing pipeline by avoiding the need for complex algorithms that try to correct the positions and may not even succeed at such.

In conclusion, this paper detail the design, installation, commissioning, and verification of MOGNO's Nano-station 5D metrology setup. The results are expected to give a significant enhancement in the resolution of beamline experiments, agreeing more closely with the specified beamline parameters. Further improvements are feasible and will be explored in subsequent publications.

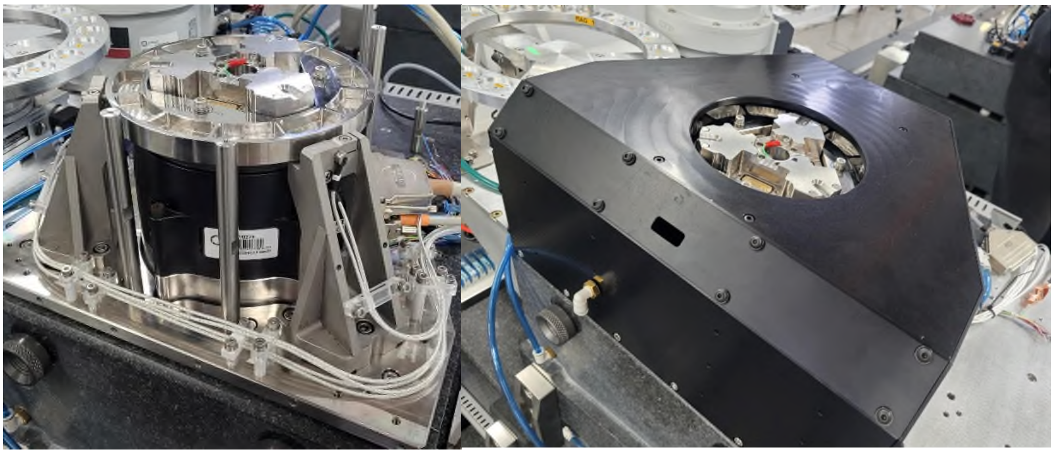

FIGURE 3. The assembled metrology setup in MOGNO Nano-station, in the left without the thermal shield and in the right, after it was assembled.

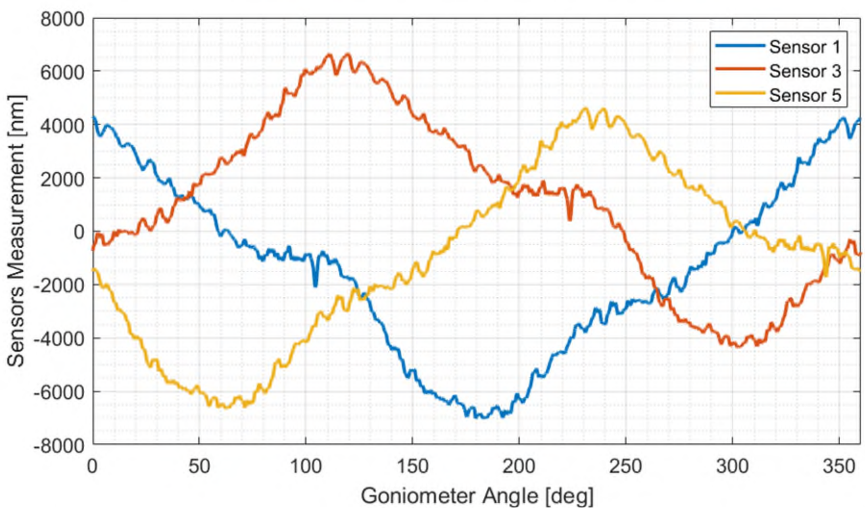

FIGURE 4. Horizontal sensors measurements as function of the goniometer positions angle.

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