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High-speed fly-scan capabilities for x-ray microscopy systems at NSLS-II

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DISCLAIMER

High-Speed Fly-scan capabilities for X-ray Microscopy systems at NSLS-II

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ABSTRACT

We are developing a next-generation scanning x-ray microscope that will significantly enhance 3D ptychographic imaging capabilities available at NSLS-II. One of the important technical tasks pertains to providing high-speed data acquisition using fly-scanning, which may hold a significant advantage over step scanning. The developed state-of-the-art x-ray microscope is EPICS-compatible and utilizes piezo actuators for fast raster scanning. The position is monitored by laser interferometers (or native encoders) and transferred to an FPGA-based device (Zebra box), which outputs detector trigger signals at a high frequency. The developed system is supported in a standard NSLS-II controls environment and can be implemented at existing and to-be-developed beamlines. At present, a similar fly-scanning capability is deployed at Submicron Resolution X-ray Spectroscopy (SRX) and Hard X-ray Nanoprobe (HXN) beamlines at NSLS-II.

Keywords: fly-scan, scanning X-ray microscopy, data acquisition system.

1. INTRODUCTION

X-ray microscopy is a powerful characterization tool routinely applied to address emerging questions in many fields of science and technology [1-4]. For a scanning imaging X-ray microscopy system, high scanning speed can directly increase beamline efficiency and alleviate requirements for long-term stability while relaxing sample preparation constraints. In traditional step scan mode, each exposure position requires the system to stop prior to data acquisition, which may become a limiting factor when fast data collection is required. Fly-scanning is chosen as a preferred solution that helps overcome such speed limitations [5, 6]. In fly-scan mode, the sample keeps moving and a triggering system generates trigger signals based on the position of the sample or the time elapsed. The trigger signals are used to control detector exposure. The detector data and time/position data at trigger points are stored for future image reconstruction. NSLS-II SRX and HXN beamlines use fly-scanning technology for their data acquisition system. Some of the NEXT-II & III endstations (being planned or under construction) will also utilize a similar approach. All these systems will be controlled by the Experimental Physics and Industrial Control System (EPICS) and maintained by the controls group at NSLS-II. The operation of multiple scanning microscopy systems at NSLS-II requires In In this work, we report on the recently developed scanning x-ray microscope equipped with EPICS-compatible high-speed fly-scan capability, ready for deployment at NSLS-II.

2. SYSTEM DESIGN AND PERFORMANCE

The details of the mechanical design of the developed microscope will be discussed elsewhere. The system is capable of performing 2D and 3D ptychography measurements with high spatial resolution. The data acquisition workflow diagram of the developed position triggering systems is shown in Figure 1. In this diagram, the position changes of the sample are monitored by either the laser interferometers or the native encoders of the piezo scanner. The position changes are first converted to the AquadB signal (AquadB signal is an incremental signal, which outputs two lines of pulses, ‘A’ and ‘B’ channels, that are offset to determine the direction). That AquadB signal is then routed to the Zebra box. The Zebra box is a dedicated position monitoring and trigger generation device developed by Quantum Detectors Inc. It calculates the position by counting the AquadB steps. For every preset Nth steps, the Zebra box sends a trigger pulse to the detector. The detector acquires data once triggered. The trigger output speed of the Zebra box can be as high as 5kHz. The corresponding time and position information can also be transferred with a speed of up to 500 points/s if necessary. Finally, the EPICS

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compiles and archives all the received data. The effective scan speed is affected by the parameter setting of the scan, such as scan range, step width, exposure time, detector data size, etc.

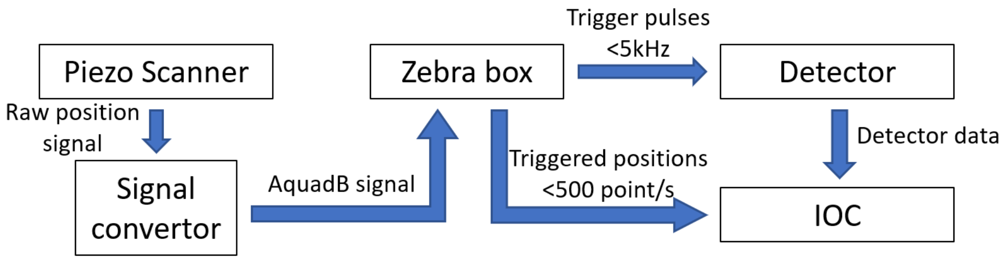

Figure 1: Workflow of fly-scanning systems at NSLS-II

At present, the developed fly-scanning capability is deployed at the SRX and HXN beamlines of NSLS-II. The SRX system was optimized for long-range sub-micrometer resolution scans [7], while the HXN system was focused on high-resolution, smaller-range scans. Figure 2 shows the microscopy system installed at the HXN beamline.

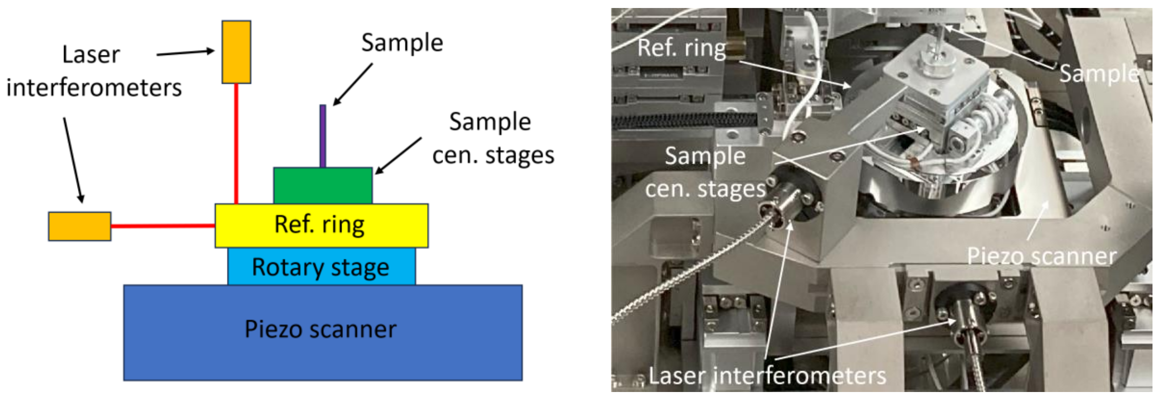

Figure 2: a) Schematic view of the HXN scanning system; b) Photo of the actual HXN system

As shown in Figure 2a, the rotary stage is mounted on a piezo scanner. The circular reference ring is mounted on top of the rotary stage with the sample centering stages on top. We used Picoscale laser interferometers (Smaract Inc.) with line-focused sensor heads to monitor the motion of the reference ring during scanning and rotations when performing 3D tomographic measurements. During sample scanning, the Picoscale laser interferometers output the position of the reference ring to the Zebra box through the quadrature signal. The developed scan system can output triggers with up to 4 nm resolution. The average scanning speed can reach up to 1,000 points per second (PTS) during long-range and high-resolution raster scans. However, the scanning speed decreases when the number of points in each line is reduced. At 500 points per line and 4 nm per step increment, the average speed was ~220 PTS, and with 100 points per line, the average scanning speed decreased to ~50 PTS. This significant decrease in the scanning speed during short-range scans is because the Zebra box can only process raster scans in a position-triggering mode. During the raster scans, the sample is scanned line by line, and the data is collected. After each line, the system needs to stop and reset before starting a new line scan. The reset introduces an overhead time which reduces the overall data acquisition speed. Moreover, there is another speed limitation related to the trigger data upload speed into EPICS. Even though the Zebra box can output triggers at a speed of up to 5 kHz, it can only upload up to 500 PTS trigger position data points into the EPICS system [8]. This does not affect the current position triggering mode but limits the application of the current system when a high-speed time triggering mode is considered and a high-speed data transfer is required. To improve the overall scanning speed during the short-range scans, we are replacing the Zebra box with a PandA box [9]. The PandA box is the next-generation programable

FPGA-based product, a successor to the Zebra box, developed by Quantum Detectors Inc. The PandA box can work with both raster and continuous scans, and its position data transfer speed is much higher than that of the Zebra box. Figure 3 shows our initial test result of the data transfer speed from the PandA box. During the test, the AquadB signal was fed into the PandAbox. The PandA box generated trigger signals and transferred the corresponding position data to a Python terminal. The trigger generation and position data transfer rate can reach up to 100 kPTS. Currently, we are in the process of transitioning our scan engine from the Zebra box to a PandA box. Upon completion, we expect to reach scanning speeds above 10 kHz. By then, we expect the speed limitations to be imposed by the detector speed, mechanical properties of a piezo scanner, and exposure time requirements specific to a particular experiment.

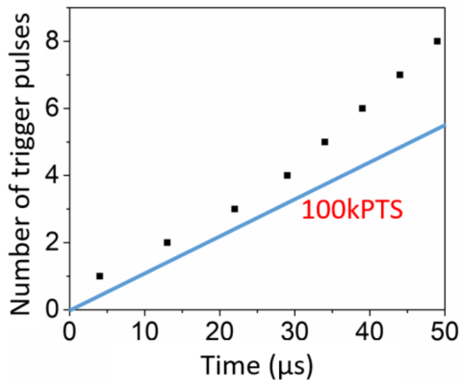

Figure 3: Position transfer speed of the PandA box

3. CONCLUSION

In this work, we introduced a recently developed x-ray microscope optimized for high-resolution ptychography measurements along with the fly-scanning platform compatible with NSLS-II x-ray microscopy systems. The developed fly-scanning platform is compatible with the EPICS environment of NSLS-II and can be maintained without the involvement of the beamline scientific staff. We discussed the limitations of the current approach when scanning in a short range as well as outlined the plan for improving its performance by implementing the PandA box.

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