LANSCE WIRE SCANNER SYSTEM PROTOTYPE: SWITCHYARD TEST*

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Abstract

On November 19, 2011, the beam diagnostics team of Los Alamos National Laboratory's LANSCE accelerator facility conducted a test of a prototype wire scanner system for future deployment within the accelerator's switchyard area. The primary focus of this test was to demonstrate the wire scanner control system's ability to extend its functionality beyond acquiring lower energy linac beam profile measurements to acquiring data in the switchyard. This study summarizes the features and performance characteristics of the electronic and mechanical implementation of this system with details focusing on the test results.

INTRODUCTION

The staff of the Los Alamos Neutron Science Center's (LANSCE) Beam Diagnostics and Instrumentation Team (BDIT) have created a prototype to replace the existing beam profile measurement system of the LANSCE facility's switchyard area. The switchyard beam lines are located downstream of the accelerator region and form and array of channels directing the beam to the various experimental areas of LANSCE. Switchyard wire scanners have a characteristically large fork and stroke relative to linac wire scanners since switchyard wire scanners encounter larger steering variations and larger transverse particle distributions than linac wire scanners.

The particle beam conditions for this wire scanner test were as follows:

- H^- particle beam.
- 1 mA peak (0.0006 mA average) beam current.
- 4 Hz, 150-us-wide particle beam macropulse and beam gating signal.

SYSTEM OVERVIEW

Control System

The overall system is summarized by figure 1. At the core of the control system is a NI compactRIO (a.k.a. cRIO or compact Reconfigurable Input/Output) enclosed in a 4U rack-mountable chassis. This chassis drives the wire scanner actuator with motor control signals and receives resolver positioning data, limit switch data, and wire secondary emission signals from the horizontal and vertically-aligned sense wires. Due to the pulsed nature of the particle beam, sense wire data is synchronized by an external beam gate signal. After the wire scanner controller has acquired the requested data, it stores the data in network-accessible shared variables. The client computer system reads these shared variables via the network and presents the data to the operator.

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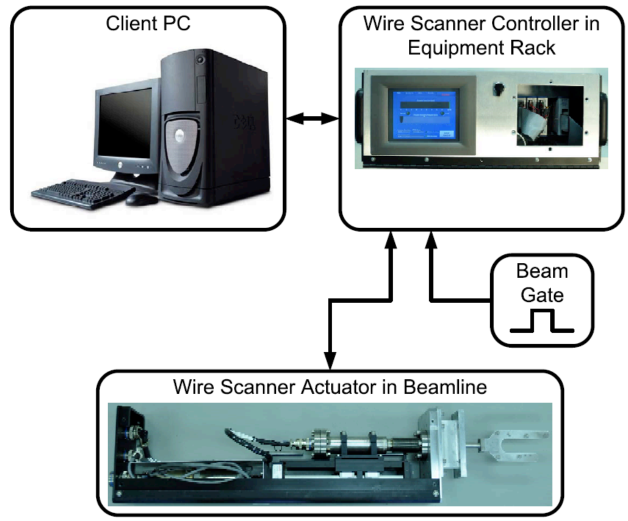

Figure 1: System block diagram.

Wire Scanner Actuator

Figure 2 depicts a model of the switchyard wire scanner actuator. This actuator has a 12-inch stroke and accommodates a fork with offset horizontal and vertical sense wires capable of intercepting beam within a 4-inch diameter aperture. The fork is supported by a linear slide stage which is driven by a NEMA 23 stepper motor with resolver feedback [2].

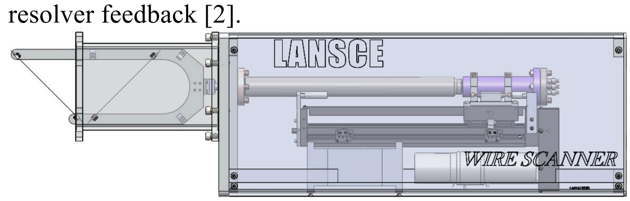

Figure 2: Switchyard Actuator Model.

TEST OBJECTIVE

Having completed a successful LANSCE linac wire scanner control system test on December 21, 2010 [1]; a similar effort was undertaken in the LANSCE switchyard. Tests of interest focused primarily on data acquisition and motion performance.

Macropulse Acquisition

The ability to acquire triggered beam macropulse samples has been incorporated into the feature set of this wire scanner control system. The macropulse acquisition feature is primarily utilized with the actuator sense wires commanded by the client to a stationary position, a mode we refer to as "wire park mode." In this mode, the client is capable of viewing horizontal sense, vertical sense, and beam gate signals simultaneously. This data is capable of being presented to the client at the rate of beam

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impingement (typically 4 Hz) utilizing a FPGA triggered interrupt to the real-time (RT) operating system of the compactRIO. Displaying the beam gate signal along with the sense wire data allows the user to observe timing discrepancies between the measured beam pulse and the data acquisition trigger. Furthermore, the user may specify how many samples shall be acquired before the rising edge of the gate and how many samples shall be acquired after the rising edge of the gate (The rising edge of the beam gate will henceforth be referred to as the "event") so long as the sum of these samples falls within the allotted number of samples (300 maximum taken at constant 2 us interval).

Digital signal processing options have also been incorporated into the controller code. The raw data presented to the cRIO's ADC (analog-to-digital converter) from the transimpedance amplifier AFE (Analog Front-End) typically contains a parasitic DC offset. Charge is derived from the wire signals though the use of integration code in the RT program. This integrator is susceptible to the parasitic DC offset signals and thus an averaging method for offset subtraction has been incorporated. Since the user can specify the number of samples to acquire before beam impingement, an average value may be derived for each macropulse over a subset of its samples. This average value is then subtracted from every macropulse sample in order to remove the offset and its corrupting effect on the integrator. Fig. 3 shows an example acquired macropulse obtained during the test.

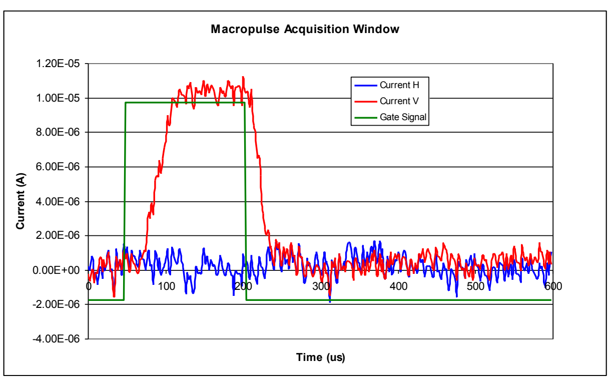

Figure 3: Macropulse window data with integration disabled.

This macropulse was acquired with 25 pre-event samples (representing 50 us in time) and 275 post-event samples (representing 550 us in time). Both horizontal (blue) and vertical (red) signals are displayed simultaneously along with the beam gate signal (green) that triggered the acquisition. Figure 4 shows a similar macropulse with integration applied.

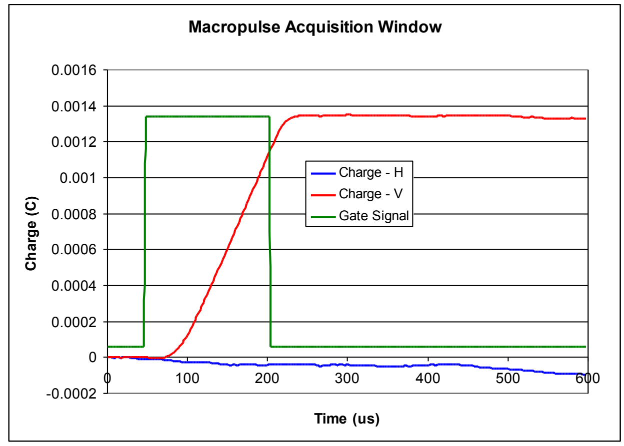

Figure 4: Macropulse window with integration enabled.

Sequential Beam Profile Acquisition

The sequential beam profile acquisition builds upon the data obtained from the macropulse acquisition algorithm explained in the last section. In this mode however, the actuator control system utilizes a sequential scan motion (more on this in the Scan Motion Performance section) to scan the sense wires through the beam cross section, obtaining the transverse beam profiles. The scanning motion of the actuator captures beam impingements in a set of prescribed locations. After tuning the macropulse acquisition parameters for pre-event samples, post-event samples, integration, background subtraction, and setting charge subtraction indices; a single charge value is derived from each set of macropulse samples. The charge value is then grouped with the position in the scan from which it was obtained. After the prescribed number of beam profile samples has been accumulated, the distribution for a beam profile may be displayed to the client. Figure 5 shows one such beam profile. This beam profile data was obtained with a centered scan spanning 75mm in width and 50 profile samples per axis.

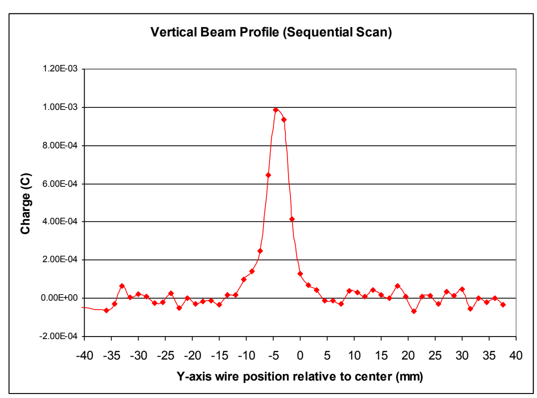

Figure 5: A vertical beam profile obtained from a sequential beam profile acquisition.

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Fly/Peak Find Mode

Like the sequential beam profile acquisition mode, the peak find acquisition mode scans the sense wires through the beam to obtain a profile. The motion control and data acquisition algorithms employ a constant rate of scan motion with macropulse data being acquired as it arrives on the sense wires. This mode is not the preferred method for obtaining beam profiles since the distribution obtained does not have a resolution that is known before taking the scan. Of primary benefit however, is this mode's ability to rapidly acquire data detailing the beam's approximate peak location and width. As such, we have incorporated the ability to locate the peak charge and its associated location for each axis. Figure 6 demonstrates the result of a peak find scan.

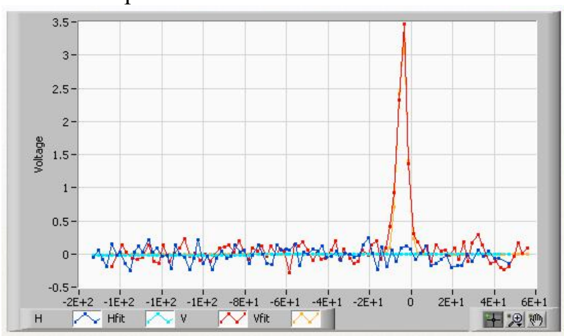

Figure 6: A fly/peak find mode scan.

Figure 7 shows the resultant peak find-related analysis.

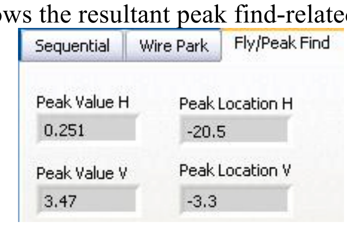

Figure 7: Peak find analysis.

The peak find data for the vertical axis confirms the peak value and location data observable in figure 6.

Scan Motion Performance

Of particular importance was the ability of the system to obtain macropulse data at the rate of at least 4Hz for the sequential beam profile acquisition mode. More specifically, it was desired for the system to complete the following operation in under 250 milliseconds: 1) acquire a 600us window of macropulse samples at the present location, 2) transfer those samples from the FPGA to the RT, 3) move to the next measurement position, and 4) repeat until all desired scan data has been obtained.

Figure 8 details a portion of the motion data acquired for a sequential beam profile scan similar to that which acquired the profile data of figure 5. This graph shows the commanded position (blue), measured position (pink), and beam event occurrences (green). As can be seen from the motion data, this wire scanner was capable of capturing a contiguous stream of macropulses beginning from about 27 mm onward. This confirms our desire to operate the sequential scan positioning within 250 ms.

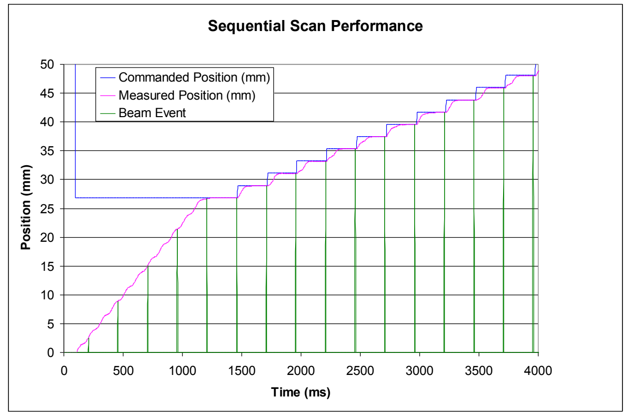

Figure 8: Sequential scan motion performance.

Actuator Fork Stability

Prior to the installation of the wire scanner, data relating to the fork stability was obtained (Figure 9). Since the switchyard wire scanner has a large cantilever arm, concerns arose over whether or not the sequential scanning mode would excite potentially large oscillatory modes in the fork. The results show excursions from the mean of about 0.2 mm, translating to sub-0.1 mm excursions in X and Y and meeting our requirements.

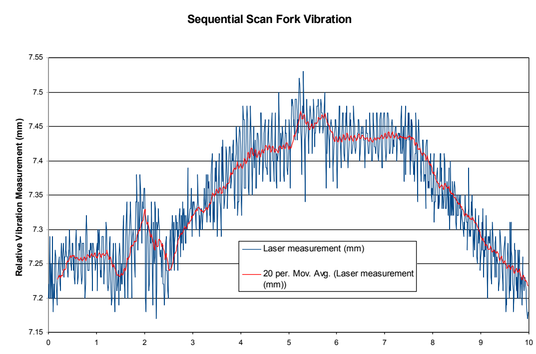

Figure 9: Switchyard actuator fork vibration.

SUMMARY AND FUTURE WORK

This wire scanner control system has thus far proven itself to operate as desired within the accelerator beam lines and now within the switchyard beam lines with the fundamental functionality having been integrated and tested. Development efforts are progressing in the areas of robustness and EPICS (Experimental Physics and Industrial Control System) integration.

REFERENCES

[1] Sedillo, J., et al. "First Test Results of the New LANSCE Wire Scanner," PAC'11, New York, March 2011, MOP236; http://www.JACoW.org

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